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CONTOURS OF CALIFORNIA

By

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ADMINISTRATIVE REPORT LJ-97-04C

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CONTOURS OF CALIFORNIA

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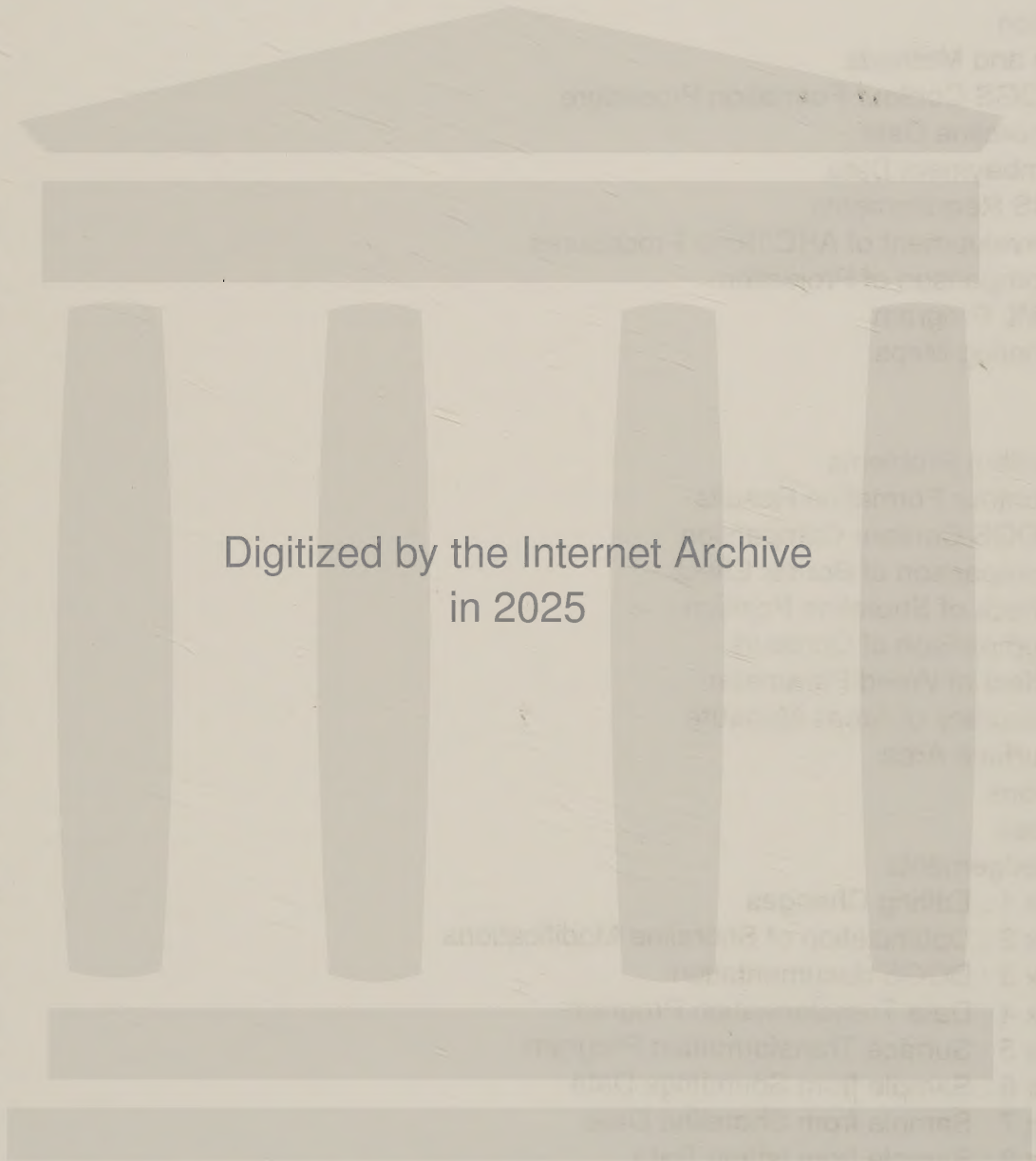

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Introduction

This project gathered data and developed procedures to measure the area of the spherical surface at sea level above a contour line at a specified depth off of the California coast. Later, the area measured can be limited by certain types of sea bottom and other factors. The purpose of the project was to measure the amount of juvenile halibut habitat available off of California. The density of halibut can be measured by sampling with a trawl. When the density is multiplied by the habitat area, the number of juvenile halibut possible along the California coast is estimated. The process is flexible and repeatable incorporating further information on which areas and depths should be measured. Of course, this procedure will also be useful for many other projects.

Soundings data from the National Oceanic Data Center (NODC) were provided through Jerry Gault (Seattle HAZMAT). The contour lines were originally drawn and the data was edited using the Digital Optimization of Grid Systems (DOGS) program, version 6.0.2, (a Macintosh program also from Jerry Gault). The soundings (from the National Oceanic Data Center, NODC) were then input into a Geographical Information System (GIS), ARC/INFO, version 7.0.4, to allow larger areas to be examined at one time and to allow for the measurement of the areas. This program provides the flexibility that allows the planimetric area above a certain depth to be measured (Appendix 9).

The DOGS program provides an excellent interface to edit the raw sounding data and remove errors. DOGS also provides the capability of examining the data by survey, which shows up most of the location errors. It also allows us to examine the data by contouring the depths to different intervals and highlighting them to look for other points that are out of place.

After finding the outliers, I selected them in DOGS and deleted them from the rest of the analysis. DOGS includes contouring capability but no area measuring capability. The contour lines from DOGS are not compatible with ARC/INFO's TIN creation. Therefore, the sounding data edited in DOGS was transferred to ARC/INFO for further processing.

Materials and Methods

Two sets of procedures were used in this project to determine contour lines and areas between them. The DOGS procedure was used to edit the raw soundings data to remove errors. Then the edited soundings data were loaded into ARC/INFO to generate the final contours and estimate the areas.

DOGS Contour Formation Procedures

To provide a complete record, the following information on how to produce contours and edit data in DOGS is provided, even though the final contours were produced in ARC/INFO instead.

Depth measurements at specified latitude and longitude from the NODC were input into DOGS. The data covered from latitude 32 degrees north to 42 degrees north for between 1 and 3 longitude degrees offshore. Several hundred of thousands data points were used. These data came from many different cruises over many different years. More data were measured close to the coast, but the position and depth of the sounding data depended on the location of the cruise that measured the information. The soundings were inspected for errors - points that did not fit the rest of the pattern.

Contours were produced in two steps. The size of the squares processed depended on the capabilities of the Macintosh. The depth data was aggregated into 1 degree squares for the editing step and 20 minute squares for the contouring step. Because of the smoothing required in the shoreline, embayments were contoured separately using the data for the embayment.

The depth data were translated from the NODC files into a form that the DOGS program could accept in one degree squares. These files were named after the south-

eastern point, i.e. 33-117. After the squares were translated into DOGS files, they were renamed by adding ent1.txt, i.e. 33-117-ent1.txt.

These one degree squares were then checked for points that did not match the rest of the data. These points could have been recorded with the wrong depth, the wrong location, or with the decimal point misplaced. If the depth somehow got lost, it would have a zero. If the depth was lost before the adjustment to mean low low tide was done, the point might have a non-zero but very low number. Other points were deleted because they used to be accurate. Some of the old surveys in the embayments did not match the coastline since the surveys were done before these areas were dredged. The old surveys in dredged areas were easy to detect because they conflicted with the modern day coastline and recent survey data. Mission Bay, San Diego Bay, Los Angeles Harbor, and a few other small harbors in that area are the harbors where surveys were taken before the bay was modified (Appendix 1). All these errors were detected and removed from the data before contouring.

To detect errors, I checked to see if all of the points in each survey were in the same area. If one of the survey points was not with the other ones, the location might be wrong and the point was deleted.

Errors were also detected by creating raster contours which show trends in bottom depth as color gradients. If there were any data points much shallower or deeper than surrounding points, the raster contours formed a small ring of dense contours, a "bull's eye". The bull's eye was examined to determine whether the cause was one point or

several. If it was caused by one point, that point was deleted. If several points caused it, the data was retained because the bull's eye was probably the top of a seamount or other feature.

The third way to check for bad points was to see if any zeros occurred outside the 30 m depth contour. I also checked histograms of depths of points to detect points much deeper than other points in the same area or survey.

When all these points were detected, they were removed from the data and a corrected one degree square was saved. These files were named after the south eastern most point, followed by ent (for entire square) and cut (for having been edited) , i.e. 33-117.ent.cut. The exact changes made to each square are noted in Table I. After the one degree squares were edited, they were divided into nine 20 minute squares. The names for these smaller squares had the location of the degree square, then a number designating one of nine. The numbers rose from the south-east one to the west, then the north. For example, the file 33-117-min5.txt is the edited square of data from 33 degrees (d) 20' 117 d 20' to 33 d 40' 117 d 40'. These smaller squares were small enough to be contoured with DOGS on the Macintosh with 32 Mb memory.

Shoreline Data

Before contouring some changes had to be made to the data describing the shoreline. The shoreline data was originally digitized off of a map at mean low low tide. The file of the whole coast was Calshor.txt. Each degree square and smaller had its own overlay file, labeled the same as the data file, but with an .ovl ending, i.e. 33-117.ent.ovl. The shoreline data generally matched the sounding data at zero meters, except in areas of large slope near the shore where the points near shore are a few meters in depth or in some small embayments where the points near shore may be less than zero.

This optimization was required because of the large scale of the data. With so many points to contour in these 20 minute squares, DOGS was forced to have a simpler coastline to work on. Three algorithms were used to optimize the shoreline in DOGS - enhancement, rolling BB, and the delta epsilon. The commonest parameter values for shoreline optimization were 5000 km for the enhancement, 5 m for the rolling BB, and 500 m and 250 m for the delta epsilon procedure. The smoothing algorithms removed points from the raw shoreline by the three methods. The enhancement added points 5000 km apart where there were no points closer. Because DOGS made no differentiation between the shoreline and the border of the square, this process worked on the borders that were not on the shore, where there were only the corner points to determine the outside line of the square. The borders were defined by noting these points with the shoreline mark tool at the time of triangulation and contouring (Appendix

1). The rolling BB erased any variations in the shoreline that were smaller in radius than the number of meters specified. This erased small streams and wiggles. The delta epsilon procedure removed points that were too close to one another and smoothed the shoreline the most. If the default optimization parameter values did not simplify the shoreline enough to allow DOGS to contour and triangulate, other parameters were tried (Appendix 2).

Embayment Data

Later, the embayments that contained data were contoured separately from the rest of the data. These much smaller blocks required little or no optimization, allowing greater accuracy in the important areas inside these embayments. The embayments selected had data. The embayments contoured were San Diego Bay, Mission Bay, Newport Bay, Los Angeles Harbor (in 4 pieces), Marina Del Rey, two harbors in the 34 d 119 d square, one harbor in 35 d 120 d square, 2 harbors in 38 d 123 d, and San Francisco Bay (in many pieces). Most of the files are organized by location and 'harbor', i.e. 33-117.harbor. The ones from San Francisco Bay start with the bay designation.

The values of the control parameters for the actual contouring were more constant than the ones for the shoreline optimization. DOGS created a triangle grid that was used to interpolate for the contour lines for every meter from 0 to 128 meters. The data were added to the grid one at a time until the stopping point was reached. The stopping point was to do every point in squares with fewer than 30,000 points. DOGS either could not or took too long to contour squares with more than that number of points. When there were more points in the square, the stopping point was set to the maximum absolute error in depth as less than 1 meter. When the maximum error in height of the triangulation grid was less than 1 meter, DOGS would stop adding points to the grid (Appendix 3).

GIS Requirements

As described above, DOGS was useful for editing the data, but could not calculate the areas. A GIS was needed to calculate the areas. The GIS needed to be able to input soundings files and to measure the area above a certain depth. It also needed to delineate regions to calculate the area within. Preferably, I could load the whole coast at one time. Finally, the GIS must calculate the area within the region. It would be preferred if it can calculate the area automatically from the designation of the region. The depths between which the area will be calculated should be able to be specified. The area should be easy to calculate once the soundings were input. It also has a complete programmable macro language that enabled me to automate most of the work to calculate the area. ARC/INFO 7.0.4 for UNIX fit all of my criteria.

The edited soundings were input into ARC/INFO and then processed into the final contours and the area measurements. Other advantages of ARC/INFO are :

1. Area above any depth can be measured when the entire process is done in ARC/INFO.

2. ARC/INFO had the capability to work with blocks of one degree or even larger, saving time in the processing and in future applications.

3. ARC/INFO does some smoothing of data and shoreline but with a simpler algorithm. It removes all points within a certain radius of another. Normally, less than 1%

of the soundings or the shorelines are removed. This smoothing can also be removed from the procedure.

4. The edited soundings were input into ARC/INFO instead of the contour lines because contour lines make very poor TINS. TINS made from contour lines have too many data points along the line and too few data points between them. When the TINS are created, the data points are formed into triangles with those closest to them. Thus, with TINS from contour lines, many triangles with all three vertices at a single depth (flat triangles) are formed, causing problems in analysis, especially in the measurement of area at depth which we need here.

5. The TIN data structure in ARC/INFO creates triangles between every point. Thus, it works well with irregularly spaced points. The TIN is similar to the triangle grid used to create contours in DOGS. With a TIN, area above a certain depth as if it were projected on the surface can be calculated with one command. Another advantage of a TIN is that breaklines can be created. These are lines that cannot be crossed, like the shoreline in this project.

Development of ARC/INFO Procedures

The first step was to translate the data from the soundings format into a format ARC/INFO would accept. As described above, the soundings, obtained from the HAZMAT office through NODC, were edited in DOGS to remove points with errors in depth, latitude or longitude. The edited soundings data were modified manually in a text editor to change the numbers in the first column to 1's, to make the longitude negative, and to delete the first row and add a line with 'end' to the last line in the file.

I wrote a TurboPascal program for the PC, tranform, to translate the coast files from the DOGS output format into ARC/INFO ASCII input polygon files (Appendix 4). All of the points for the shoreline must form an enclosing polygon of all of the soundings. This polygon surrounds the data, letting ARC/INFO know where not to interpolate because it is on dry land. Thus, the shoreline data from the Macintosh was loaded onto the PC, transformed by this program, and divided into islands and the general shoreline. Once the coast file was divided into the different islands and the entire shoreline, the islands were labelled as erase polygons for input into the ARC/INFO TIN (Appendix 5). The shore polygon was also edited to copy the first point in the file to the end (Appendix 8). Then the file was checked for consistency.

The second step was loading the data into ARC/INFO. The files, once transferred from my PC to the UNIX computer with ARC/INFO, were used to create a TIN in ARC/INFO (Appendix 10). Once the TIN was created, it needed to be projected. The

projection matches the latitude and longitude used from spherical Earth to a flat plane representation that area can be measured on. Many different projections are available in ARC/INFO. Some save the shape of the features on the map, some save their direction, and some save their area. Since I wanted areas calculated using the TIN to be accurate, the possible projection algorithms were two equal-area projections (the relative area is the same as that in nature), Albers Conic and Cylindrical. Albers Conic is for areas longer in the east and west direction than in the north and south direction. So, I projected the TIN by the Cylindrical method. Projecting a TIN causes errors by stretching the triangles that constitute a TIN. To avoid these errors, the TIN must be changed into a coverage, another form of geographical representation in ARC/INFO, projected, then reformed into a TIN. Thus, the TINS were changed into point coverages for the soundings, the shoreline, and the islands. These coverages were then projected using the cylindrical projection with the minimum latitude equal to 32 and the maximum latitude as 42, the minimum longitude as -125 and the maximum longitude as -117. These coordinates encompass the study area. The resulting coverages are processed in ARC/INFO using the build and clean command to reform the topology of the coverage. All of these coverages are then combined into one TIN for each degree. Once the final TIN is formed, calculating areas above a depth for the whole degree is a simple one line command. This projection allowed ARC/INFO to assign the units of square meters to the areas calculated.

After the projection, command VOLUME in ARC/INFO calculated the area above a certain depth as if it were projected on the surface of the water and wrote it to screen or to a file. It also calculated the volume within the shape, with simple subtraction estimating the area between contour lines.

Comparison of Projection

Because the data must be projected onto a two dimensional map to calculate areas of the TIN, a projection and its parameters must be chosen. The cylindrical projection was chosen from those available in ARC/INFO, although the Albers projection may have performed almost as well. To calculate the effect of the projection and different parameters, four different sets of parameters for cylindrical projections and two different sets of parameters for Albers projections were used on the latitude 32, longitude 117 data, a one degree square which is the size of the data normally processed. The areas calculated were compared to measure the difference caused by the different projections.

The parameters for the cylindrical projection are two points, defining a square. The first set used was the same as in earlier processing, with points 32, 125 and 42, 117. These points were chosen because they covered the study area adequately. The second projection used points closer together, 35, 123 and 39, 119. The third projection used points farther apart, 27, 130 and 47, 112. The fourth projection used points still farther apart, 22, 135 and 42, 117. The parameters for the Albers projection were two latitudes and a longitude. The first Albers projection used the latitudes 33 degrees 40' and 40 degrees 20'. The second Albers projection used the latitudes 32 degrees 10' and 32 degrees 50'. Both used 121 degrees for the longitude.

The comparison of the areas showed that the areas were very similar from all of the projections (Figure 1a). By examining a very small section of the graph, the results can be differentiated, but results were very similar overall (Figure 1b). All of the other cylindrical projections result in areas slightly larger than the parameters used in the rest of this project. The Albers projection results in lower areas. Again, the difference is very small.

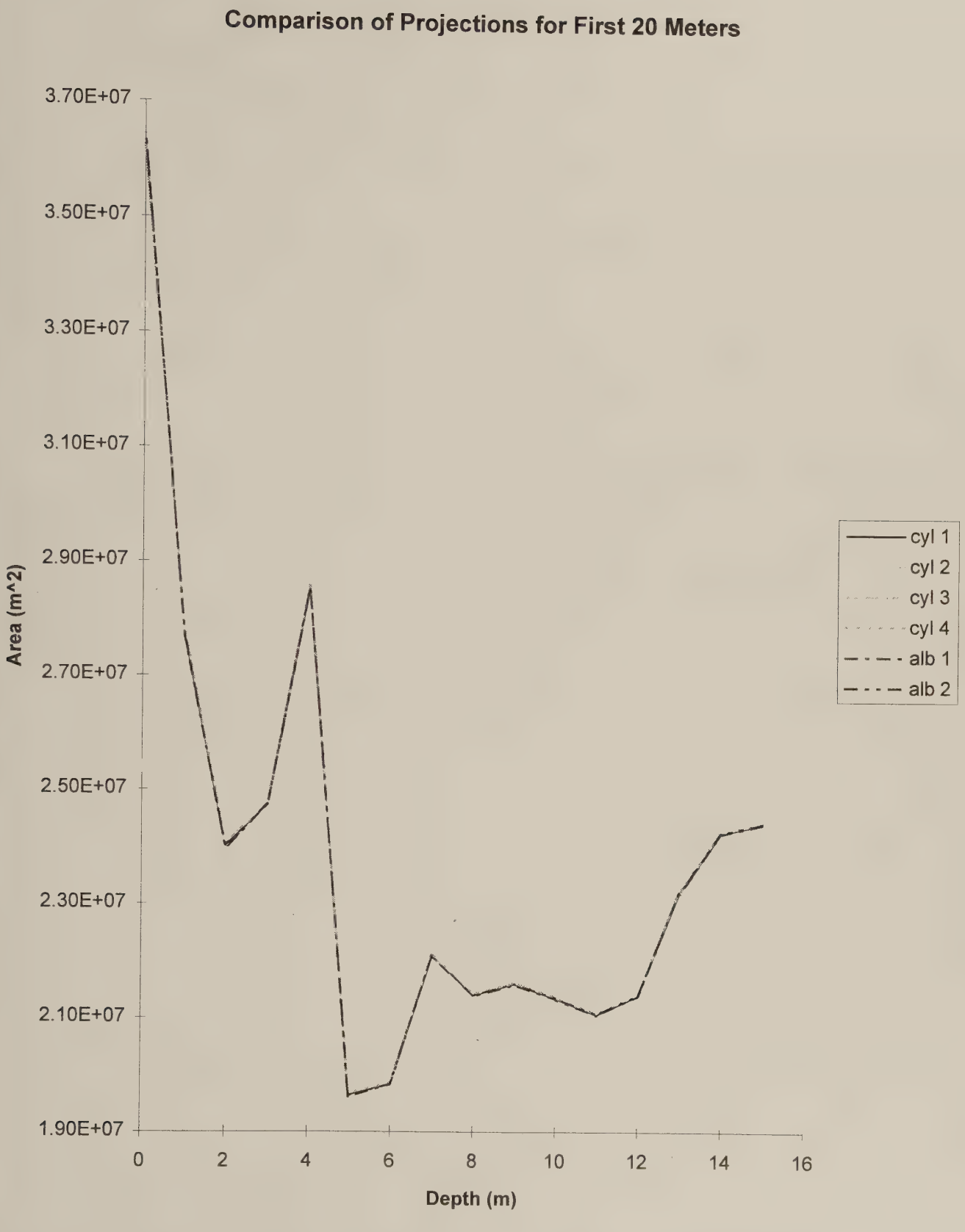

Figure 1a : Comparison of areas from 0 to 16 meters for different projections. See text for parameters of projections.

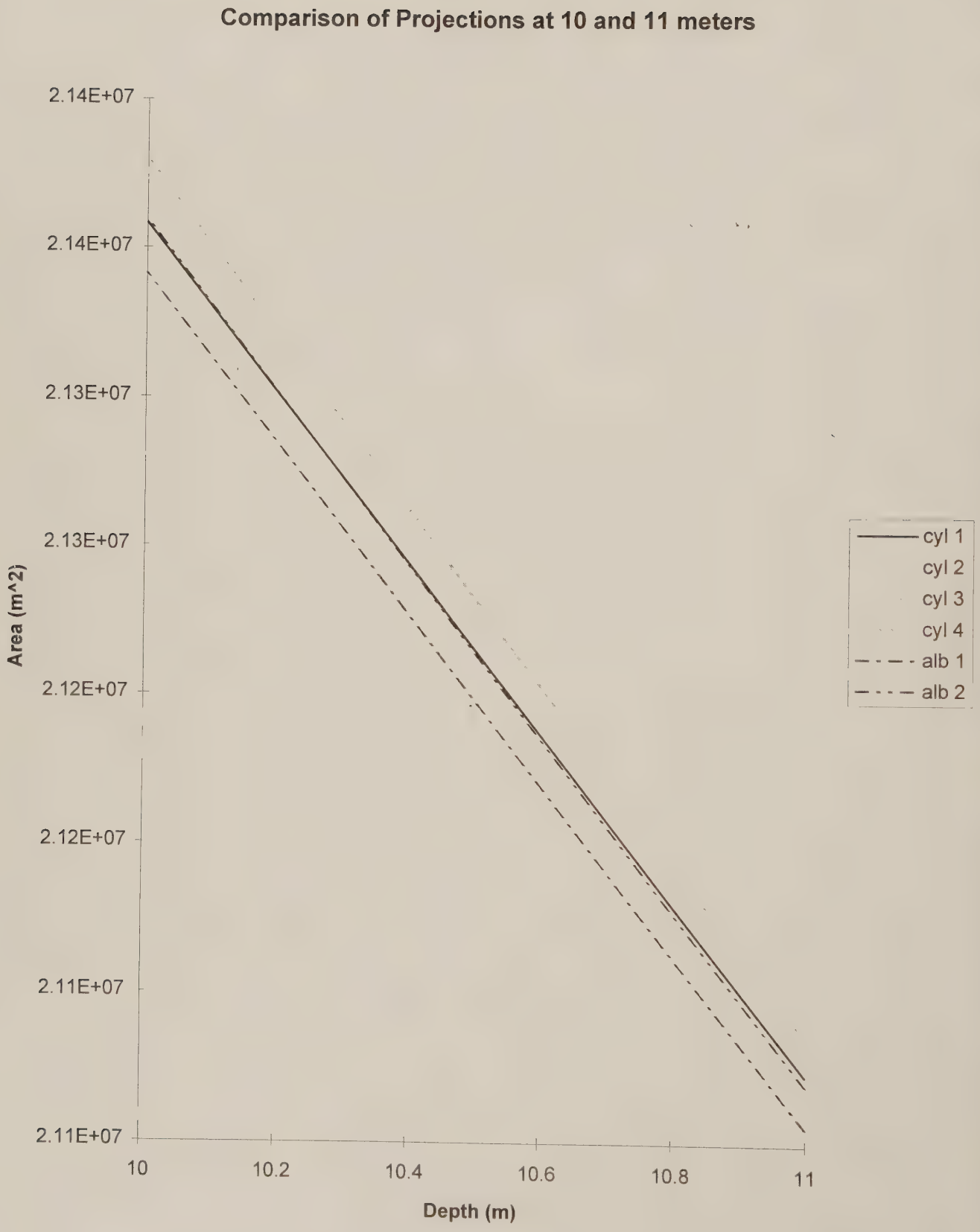

Figure 1b : Comparison of the different projections by comparing results at 10 and 11 meters depth. See text for parameters of projections.

AML program

I wrote a program in the ARC/INFO macro language (AML) to calculate spherical areas between user-specified depths and rectangular coordinates. The user simply starts up ARC/INFO from the root directory and types '&run calcarea' at the prompt. Then the user selects whether to load in the coordinates from a file or from the menu. If loading from the menu, the user selects the latitude and longitude of the degree he will be measuring, types in the exact coordinates of the rectangle, the depths he wants to collect data between, at what interval to divide the data, and the file the data should be output in. If the user is inputting from a file, the file must conform to the following format.

number of different degrees to be measured

number of different areas to measure in this degree

latitude of this degree block

longitude of this degree block

first latitude of the this area

first longitude of this area

second latitude of this area

second longitude of this area

{repeat above four lines for each area}

least negative depth to measure from

most negative depth to measure to

interval to measure on

output file name

{repeat from second line for each degree to be measured}

The program creates the TIN containing that area's soundings, measures the areas desired, and outputs results to the users file in the root directory in the file indicated. For the file input, one output file is created for each one degree square examined.

Printing Maps

At some point in the future, a researcher may wish to create printed maps of the contours in ARC/INFO or display them on screen. The following commands allow this to be done. To display on the screen, omit the display command, the postscript command, and the lpr command.

```
arcplot
display 1040 2          (then type in the file name to print out)
pagesize 8.5 11
mapextent <replace with whatever TIN you wish to print out>
surface tin <replace with same name as above>
surfacecontours <replace with number of meters between contours>
quit
postscript <file name of output> <file name with .eps>
Get out of ARC/INFO (either ^z or exit)
lpr -Plp1          (to print out on Rich Charter's printer)
```

Results

This procedure can be used to calculate the area above and at a certain depth given a file of soundings data and shoreline data for that area (Appendix 9). Areas at every meter down to 100 m will be useful for measuring the amount of habitat juvenile halibut have available.

Issues

Commercial software for calculating area above depth using soundings data is not readily available and ARC/INFO was not designed specifically for this purpose. ARC/INFo provides good, useful results, but some areas for future improvement remain. The following sections list the problems and note what progress has been made in clarifying the impact of these problems on the areas calculated in ARC/INFO.

Halibut Problems

One other problem with the calculations being performed is lack of knowledge about how the halibut react to environmental factors. Little is known about how far inshore the halibut occur, salinity preferences, how far offshore they occur, and other important factors. Like, if the fish follow the tide up and down the shore on a daily basis.

These calculations of area do not include any indication of the type of bottom that is being measured (e.g. rocky, eelgrass, or muddy). Halibut may prefer a specific bottom type, but information about bottom type along the whole range of the study area is not known.

Contour Formation Results

The errors deleted from the shoreline and the optimization of the shoreline while contouring it are at the end of this report (Appendix 1, Appendix 2). Several sources of error are possible with the contours. For example, if the contour lines were formed with too few soundings (especially if too few data were available), they may smooth out real features, affecting the calculated area for all those depths. Similarly, errors in omitting outliers would affect results.

One problem exists in the error present when all the points are not used by DOGS. The number of points used is normally greater than 30,000. The largest errors are distributed around the square the same way as any errors. For example, from 33 d 0', 117 d 20' to 33 d 40', 118 d 0', 97,000 data points were present. Of these, 60,000 were used to derive the contours. The errors in this square were more concentrated where there was more data, inshore. Both the large and the small errors had higher concentrations offshore than onshore. Fortunately, ARC/INFO uses all of the data points, eradicating this problem.

Problems with the number of soundings could also be present. The soundings are dense in most areas to >100 m, so there should be enough to contour the surface accurately.

Another problem could be the effect of the tide. All of the data is supposed to be adjusted to mean low low tide. If some errors are done in this process and not caught in the preliminary examination, the contour lines and areas could be very biased.

Another problem could be caused if the area measure does not calculate the proper units. This could be caused by an incorrect projection or designating the wrong units, resulting in ill-calculated depths. Areas in some of the embayments along the Southern California coast from a previous paper can be compared to the calculated areas to determine possible errors.

Another problem could have been the precision of the coordinates in ARC/INFO. Latitude and longitude coordinates, and their projected counterparts, require high precision storage. ARC/INFO automatically stores the x and y coordinates in a TIN to double precision, the same as the calculation is done in, reducing any problem.

The major problem with this method is the lack of data from the small embayments along the coast. There were few embayments that actually had data - Mission Bay, San Diego Bay, Los Angeles Harbor and some other large embayments. Many of the small ones - Agua Hedionda and Batiquitos Lagoon - were not surveyed at all. It is known that the juvenile halibut are found in high numbers in these areas. Hopefully, this data can be obtained from another source.

The next problem develops because of a border effect on the determination of location of lines defining depth contours in ARC/INFO. The change in placement of contours is as likely to be large between one degree and another as within a degree.

However, the location of the lines near the borders are likely to be ill-defined with fewer points determining them, causing the border effect, the lines may be slightly misplaced between two adjoining blocks. Since the areas must be measured in a single block, the single blocks may be quite small. These small modifications to the ends of the lines should not have a huge effect on the areas calculated, but may have some effect. This effect is likely to be swamped by the other border effect.

Because the areas can only be measured in single block segments and the borders of the block must be set to a single depth, many very thin contour lines are pushed up against the borders. This border effect raises the amounts measured, especially for shallow depths.

Despite these possible concerns, volumes for each degree were calculated at 1 meter intervals down to 100 m (Appendix 9), producing a coast wide estimate of area of juvenile halibut habitat along the California coast.

DOGS Contour Comparison

I tested the resiliency of the contouring algorithm in DOGS by subsampling the soundings in a small area and then creating contours for each of the subsamples. Comparing the contours determined how robust the contours are with different data.

I derived a comparison of the consistency of the contours during the first part of the month. This comparison provided an idea of the maximum variability of the contours and the estimates of the areas calculated from those contours. The contours are derived by interpolation from soundings data. Error may be introduced by this interpolation. To determine the precision of these estimates of area, a contour comparison test was performed.

A test area was selected in the area most critical to halibut - between 37 degrees 20 minutes north latitude, 117 degrees west longitude and 38 degrees north, 117 degrees 20 minutes west and another segment between 37 degrees 20 minutes north, 117 degrees 20 minutes west and 37 degrees 40 minutes north, 117 degrees 40 minutes. To determine the resilience of the contour estimates to the data used, I performed a jackknife variance estimation. Five sets were chosen in random from the first set with each point having a probability of 10% of being in the subset. Five sets were chosen in random from the second set with each point having a probability of 20% of being in the subset. The

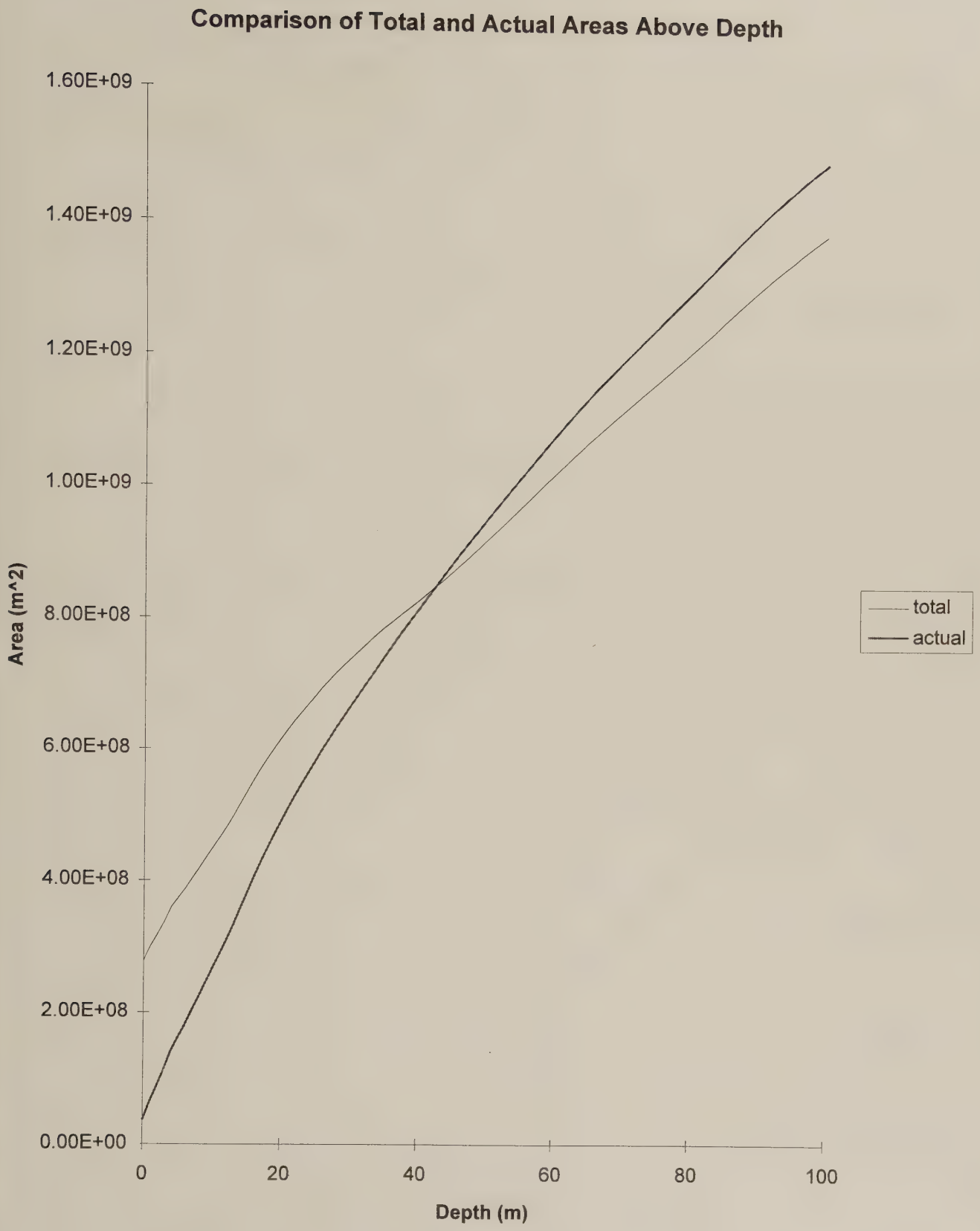

Figure 2a : Measurement of effects of border by comparison of area above depth in whole degree (actual) and in pieces summed (total).

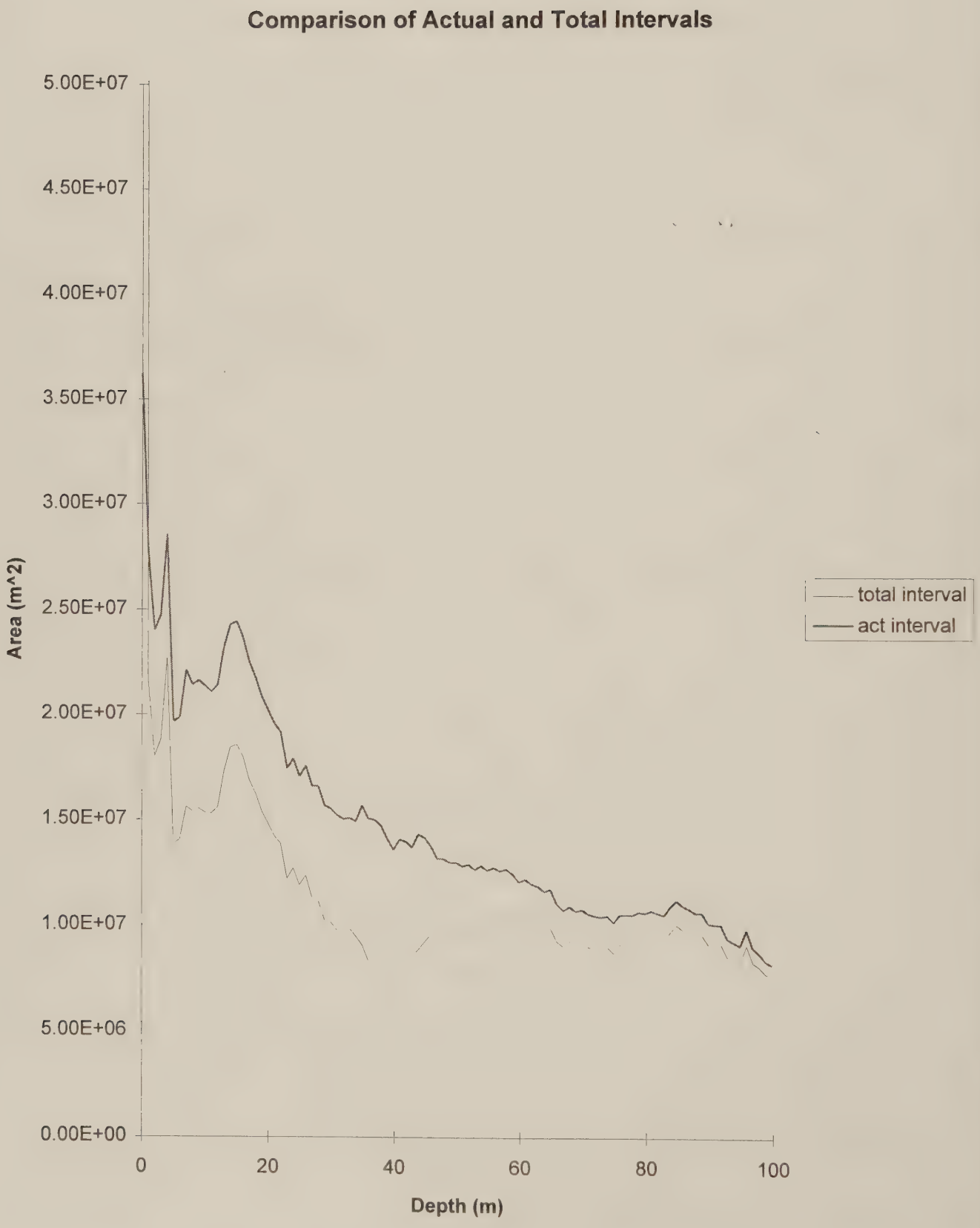

Figure 2b : Measure of the border effect by comparing the whole degree (actual) against the summation of pieces of the degree (total).

sets were contoured every meter to a depth of 128 meters and the contours were compared visually.

The first section provided satisfactory results. Only two areas of the data were above 128 meters depth. These areas were each visible and similar in shape in each of the trials. The main error was the missing deeper points caused variation in the depths of the contours.

The next section, from along the coast, was a more stringent test, also performing very well. The contour lines were wiggly parallel lines that spread apart farther offshore. The pattern for the five random sets was similar, but with fewer wiggles in each line. The lines even separated at the same time in each of the subsets as in the main section.

This useful comparison confirmed that, to the naked eye, the contouring procedure is providing consistent results. This qualitative comparison will provide some idea of the precision of the contour estimates based on the error in the contour lines. It also provided some information about ARC/INFO results because of the similarity of the algorithms.

Comparison of Border Effect

In ARC/INFO, the border around a TIN is asumed to be of a constant depth, usually zero meters. Thus, there is a very narrow band of thin controu lines between the last set of points along the border and the border itself. The area between these thin artifacts affects area calculations. The magnitude and importance of this effect decreases with greater area size. To measure the extent of this effect, the areas of block 32 latitude, 117 longitude were calculated as a whole and in six pieces. The differences between the summed total and the actual areas is caused by the border effect (Figure 2).

The actual area, from the one degree square, above a depth is less than the summed total areas, from the six pieces, above that depth above 45 meters and greater below that point (Figure 2a). The border effect is largest at the very shallow depth intervals, about three times near the surface. The interval area is always greater than the summed interval area except for zero meters (Figure 2b). The effect is about 20% down to 50 meters.

Because of this comparison, the shallow calculated areas, especially from small segments of the coast, should be carefully examined to determine if the border effect is damaging the precision of the estimated areas.

Check of Shoreline Position

To check that the position of the shoreline as described in the available data was accurate, three points were chosen from a USGS map. The longitude and latitude of these points were measured in both DOGS and from the map. Since the ARC/INFO shoreline is derived from DOGS, one comparison sufficed to check that the points were constant.

The first point was on Catalina Island, at Twin Harbors, in the inner point of the inlet on the ocean side. On the map that point was at 33 degrees 26.25' north latitude and 118 degrees 30.0' west longitude. In DOGS, it was at 33 degrees 26.17' north latitude and 118 degrees 30.14' west longitude. The second point was the southernmost tip of North Island in San Diego Bay. On the map that point was at 32 degrees 41.0' north latitude and 117 degrees 14.0' west longitude. In DOGS, it was at 32 degrees 41.06' north latitude and 117 degrees 13.36' west longitude. The third point was the tip of Point Conception. On the map that point was at 34 degrees 27.25' north latitude and 120 degrees 29.25' west longitude. In DOGS, it was at 34 degrees 26.87' north latitude and 120 degrees 28.27' west longitude. Thus, the point on the map and the point in DOGS were less than one minute apart in all cases.

However, the resolution of the USGS map was much higher than the shoreline in DOGS. The shoreline was much smoother in DOGS than on the USGS map. The

difference in resolution may have a large effect on the final areas calculated. Thus, another, finer resolution, shoreline for the ARC/INFO area calculations should be obtained.

Comparison of Contours

Two small sections of the coast, Sycamore Canyon Reserve and Vandenberg Reserve, were contoured in both ARC/INFO and DOGS. The comparison of unique details of each of the sections showed that the two sets of contours were identical. Thus, the lines that ARC/INFO creates as its contours are the same as those that DOGS created.

Effect of Weed Parameter

ARC/INFO, by default, does not use all of the data available to form the TIN. It calculates a weed parameter that deletes all data within that radius of another datum, smoothing out the TIN. Because of the possible effects on the areas calculated, a comparison of the areas calculated with the default weed parameter and a weed parameter of zero was performed (Appendix 9).

Disabling the weed parameter, by setting it to zero, made a difference, especially along the coast and for those areas above 20 meters depth. The result without the weed parameter is usually smaller than the areas with it. Thus, more complexity exists at smaller intervals that may require better data to ensure more precise area calculations. I recommend that the weed parameter be set to zero in ARC/INFO.

Accuracy of Areas Measure

To test the accuracy of the areas calculated by ARC/INFO, a program written by Larry Eber was used to calculate the areas between ten meter depth intervals from 200 meters to ten meters in 34 degrees 30' to 34 degrees 0' and for 100 meters to 180 meters for 36 degrees 30' to 36 degrees 0' (Eber 1992). The contour data used by Eber's program was originally digitized from bathymetric charts. In ARC/INFO, I calculated the area between those ten meter intervals in each of the three degree grids for the 34 degree latitude area and for the two from the 36 degree latitude area. When these were summed together, they were compared against the areas from Larry Eber's program (Table 1).

Table 1 :

Comparison of Areas From Two Programs

34 degrees latitude depth (m)	area (km^2)	Eber's area (km^2)	amount difference	% difference
200	75.4	88.14	-12.74	-16.90%
190	73.92	69.83	4.09	5.53%
180	68.06	55.69	12.37	18.18%
170	69.08	58.59	10.49	15.19%
160	67.15	79.65	-12.5	-18.62%
150	68.41	59.58	8.83	12.91%
140	72.94	68.22	4.72	6.47%
130	87.7	76.08	11.62	13.25%

120	95.95	84.66	11.29	11.77%
110	170	159.56	10.44	6.14%
100	267.7	300.24	-32.54	-12.16%
90	329.3	322.32	6.98	2.12%
80	257.7	272.99	-15.29	-5.93%
70	238.9	218.1	20.8	8.71%
60	225.9	226.16	-0.26	-0.12%
50	255.9	198.39	57.51	22.47%
40	267.6	245.22	22.38	8.36%
30	315.4	270.49	44.91	14.24%
20	287	235.66	51.34	17.89%

36 degrees latitude

depth (m)	area (km^2)	Eber's area (km^2)	amount difference	% difference
180	12.17	11.3	0.87	7.15%
170	12.95	12	0.95	7.34%
160	14.44	13.68	0.76	5.26%
150	17.54	16.88	0.66	3.76%
140	19.5	22.13	-2.63	-13.49%
130	26.6	26.35	0.25	0.94%
120	40.96	42.98	-2.02	-4.93%
110	78.02	75.75	2.27	2.91%

Comparisons of the summed areas and Eber's areas show similarities. The differences in the 36 degree section represent 4 to 8% of the total area. The differences in the 34 degree section are much larger, from 10 to 20% of the total area. This larger difference may be caused by Eber's program measuring less offshore than ARC/INFO measured, resulting in the larger areas measured by ARC/INFO.

Surface Area

An attempt was made to not only measure the area available to juvenile halibut by the planimetric method, but also to measure the actual surface area of the bottom available to halibut. Unfortunately, ARC/INFO does not implement this measure as easily as planimetric area for TINS. A method was derived to create separate TINS for each interval, then measure the surface area of those, but the results were not correct, resulting in negative areas for some intervals. A further release of ARC/INFO may have a function to assist in the calculation of surface areas like that of planimetric areas.

Conclusions

This project developed a method to measure planimetric area between different depth intervals anywhere off of the California coast. ARC/INFO is readily capable of taking on projects of this complexity and size.

Several problems and concerns exist at this point, however. The difference between the projections was much less than 1%. The measure of the border effect led to an estimate of possibly large errors in the shallower depth intervals. The shoreline check resulted in a recommendation for a more detailed shoreline if one is available, but the accuracy of the shoreline was one minute. The contours from DOGS and ARC/INFO are very similar. In fact, they are indistinguishable by eye. The comparison with the weed parameter set to zero concluded continuing to set it to zero, but only a 1% error when it is not. The areas compared to the ones from Eber's data, show a difference of 4% to 20%. Perhaps, given the possible errors in Eber's data, these results were encouraging.

Problems that are more important arise from the border effects, which cannot be erased but may be measured, the lack of knowledge of bottom type over large areas of the coast, and the low resolution of sounding data over much of the coast, especially shallow embayments. The scale over which the measurements of area seem accurate are down to several kilometers. At a smaller scale than that, the error in the area will be too large.

Further research can expand the programs written to do more analysis. Further work on the border effect would also be useful. Most of all, some other reasonable estimate of the area at different depths on the coast, especially at a small scale would be useful to compare these results against. More soundings in the shallow embayments and more knowledge of halibut and its habits is needed to fully implement this method. Finally, this data needs to be used to measure the amount of habitat available to juvenile fish.

References

Eber, L.E. 1992. NOAA/NOS Bathymetric digitization program RUNBATHY. NMFS, SWFSC Admin. Rep. LJ-92-26: 12p.

Acknowledgements

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Appendix 1
Editing Changes

This appendix lists the soundings removed from the NODC data in DOGS before they were input into ARC/INFO. In this tables, the one degree square is designated by a two number label. The first number is the latitude, the second the longitude of the south-east corner, i.e. 34-117 is the square north and west of the point 34 degrees latitude and 117 degrees longitude. If the square is 20', the letter after it designates which one of the nine 20' squares in the 1 degree square it is. The scheme starts with A in the south-east corner, moving west, then north, i.e. 34-117E is the 20 minute square between 34 d 20' 117 d 20' and 34 d 40' 117 d 40'. The contour files are named the same as the data files, but with a .cont ending.

32-117

one bad point at depth	32 d 29', 117 d 3'
several bad points in harbor	32 d 43', 117 d 11'
two out of date surveys	
Mission Bay 5665	
San Diego Harbor 5680	

32-118

- bad survey 9246
- several zeros in 9112 and 9111
- bad point in 5601, point 23489
- bad point in 5758, point 20804

32-119

- zeros in 9068, 9067, and 9065
- two points too deep, >8000m

33-117

one point too deep, >2000m

33-118

bad survey 9246
out of date surveys in Los Angeles harbor 5486, 5429
out of date survey (5397) that required deleting points closer to shore than
33 d 50.40' , 118 d 24.12'
and 33 d 50.28' , 118 d 23.58 '
out of date survey (5396) that required deleting points closer to shore than
33 d 51.12' , 118 d 24.18'
out of date survey (5363) that required deleting points closer to shore than
33 d 57.48' , 118 d 27.90'

33-119

mislocated point 33 d 57.60', 118 d 28.75'
mislocated point 33 d 0.37', 119 d 26.09'
4 zeros in 9067

33-120 no bad points
34-118 no bad points

34-119

3 too shallow points 34 d 24.22', 119 d 41.39'

34-120

2 zero points above island on the east
one too deep point > 8000m
bad survey 10171
mislocated point 34 d 19.23', 120 d 15.57 '

35-120

low values around 35 d 7', 120 d 40' and 35 d 26.07', 120 d 15.57'
several zero points offshore 35 d 32.32, 121 d 06.68' and
35 d 34.18', 121 d 07.26' and 35 d 35.29', 121 d 07.74' and
35 d 40.58', 121 d 20.84'
misplaced point 35 d 20.51', 121 d 32.52'

36-121

too deep point 36 d 22.46', 121 d 57.92'

36-122 no bad points

37-122A
too shallow points <-7 m
zeros in the mouth of the bay
zero in middle of the bay

37-122B
too shallow points <-7 m
zero point 37 d 55', 122 d 25'

37-123 no bad points

38-122
zero points 38 d 03.68', 122 d 06.12' and 38 d 03.67', 122 d 6.68' and
38 d 5.16', 122 d 25.66' and 38 d 00.16, 122 d 26.83'

38-123
deep point 38 d 32.83', 123 d 18.37'

39-123 no bad points
39-124 no bad points

40-124
zero points 40 d 12.37', 124 d 18.91 and 40 d 12.37', 124 d 18.93' and
40 d 12.03', 124 d 18.30 and 40 d 14.33', 124 d 21' and
40 d 25.86', 124 d 26.38' and 40 d 26.47', 124 d 25.78' and
40 d 26.47', 124 d 25.80'

41-124 no bad points

Appendix 2
Optimization of Shoreline Modifications

In order to check the contours easily, they need to be formed in DOGS. This appendix lists the shoreline modifications for half the data necessary for contouring in DOGS. The labeling scheme for the squares is the same as in Appendix 1.

Square	Enhance	BB	Delta	Epsilon
35-121,G	500	5	200	50
35-121,H	1000	5	200	50
35-121,I				
36-121,B	2000	5	500	100
36-121,C	5000	5	500	100
36-121,F	5000	5	500	100
36-121,I	5000	5	500	100
36-122,A	5000			
36-122,B				
36-122,C				
36-122,D	5000	5	250	50
36-122,E				
36-122,F				
36-122,G	5000	5	250	50
36-122,H				
36-122,I				
37-122A,D	5000	50	250	50
37-122A,E	1000	50	250	50
37-122A,G	1000	50	250	50
37-122A,H				
37-122B,A	1000	50	250	50
37-122B,B	1000	50	250	50
37-122B,C	1000			
37-122B,D	1000	50	500	100
37-122B,Ea	1000	50	500	100
37-122B,Eb	1000	50	500	100
37-122B,F	1000			
37-122B,G	3000	50	500	100
37-122B,H	5000	100	500	100

37-122B,I	5000			
37-123,A				
37-123,B				
37-123,C				
37-123,D	5000			
37-123,E				
37-123,G	5000	5	250	50
38-122,A	1000	5	250	50
38-122,B	1000	5	250	50
38-122,C	5000	5	250	50
38-123,A	1000	5	500	100
38-123,D	1000	5	500	100
38-123,E	1000	5	500	100
38-123,H	5000	5	500	100
39-123,C	5000	5	500	100
39-123,F	5000	5	500	100
39-123,I	5000	5	500	100
39-124,G	5000	5	500	100
39-124,H				
39-124,I				
40-124,A	5000	5	500	100
40-124,B	5000	5	500	100
40-124,C				
40-124,D	5000	5	500	100
40-124,E	5000	5	500	100
40-124,F				
40-124,G	5000	0	750	200
40-124,H				
40-124,I				
41-124,AD	5000	50	250	50
41-124,BE	5000			
41-124,CF				

Appendix 3

This appendix is the documentation provided by Jerry Gault of Hazmat, Seattle (jerry_gault@hazmat.noaa.gov or (206)526-6323) with the DOGS program. This appendix does not include the many pictures included in the original formatting because of compatibility problems with the printer.

Digital Optimization of Grid Systems (DOGS)

Introduction

DOGS is used to analyze and order bathymetric data obtained from the National Ocean Service (NOS). The data, originally contained in one degree square text files, is translated by DOGS into a format it is able to analyze. Since a file may contain up to tens of thousands (or even hundreds of thousands) of data collected from various surveys, it is imperative that a smaller subset of data be extracted for use in our ocean current analysis tool "CATS". Although these files contain large amounts of data, a much smaller subset of that data may well describe the ocean topology in the region of interest. So, the challenge at hand is to select the least number of points that best describe the ocean terrain within a specified error criterion. This "ordered" subset of data can then be saved and used in subsequent current analysis.

Program Input

Initially, DOGS takes as its input a one degree square text file containing multiple types of NOS data, from which it selects only bathymetry points. The data depths are converted

to meters and relevant information such as, longitude, latitude, depth, cruise survey number, depth storage code and file line index are stored to the translated file.

Once a translated file is obtained, it can be read into DOGS for bathymetry analysis. DOGS also uses as input shoreline data files either hand-digitized, or obtained from NOS. These files are in "BNA" format. With both the bathymetry and shoreline data read in, DOGS is able to do a topological analysis of the region of interest.

Bathymetry Analysis/Optimization

Process Overview

DOGS analyzes bathymetry by creating and connecting geodesic triangles to form a topological map of the ocean terrain (also referred to as a "geodesic dome"). As data are individually selected, more information is obtained about the terrain. Starting with an initial set of relatively few triangles that encompass the region, vertex points are selected based on a specified error criterion and more triangles are created, thus refining the geodesic dome and resolving the ocean terrain with increasing topological accuracy.

Initial Conditions

The analysis begins by selecting one of two possible domain conditions: a derived "hyper-box" boundary, or a shoreline boundary. The hyper-box is an enclosing coordinate rectangle that contains the data in its "geo-boundary". It is derived by computing the maximum and minimum data coordinates and offsetting them by a small delta. The depths for these four coordinate points are computed by a weighted average of the surrounding data depths. At this point, DOGS selects the first actual bathymetry point to be used. This is done by selecting the data point closest to center, or by deriving the three-dimensional surface shape function that passes through the hyper-box coordinates, then selecting the data point with the largest depth delta from the surface.

Once the starting vertex is determined, DOGS creates the first four triangles. As with the four-point hyper-box surface, three-dimensional shape functions are computed for each of these four triangles. Each data point is then assigned the triangle number in which it is contained and its depth error is calculated. The data point with the largest error is used as the next vertex point. This process continues until all the possible vertices are obtained, or a specified error value is reached.

When using a shoreline boundary, DOGS performs a DAG-Delauney triangulation of the enclosing shoreline boundary. Unmarked shoreline points are assigned depths via a user-defined value and marked points are assigned the depth of the closest bathymetry point (see "Shoreline Mark Tool"). This triangle set is used in a similar manner as the hyper-box triangles; each data point is assigned a triangle number and its error is computed. The data point with the largest error is selected as the next vertex and the process continues.

Delauney Triangulation

DOGS utilizes Delauney triangulation to aid in creating more "equilateral" triangles. When a new vertex is determined, the "parent" triangle which contains this point is split into three triangles using this vertex as the common point. When this happens, it is not guaranteed that the resulting triangles will be as equilateral as possible. To help with this problem, DOGS looks at the parent's "neighboring" triangles to determine if a better triangle might be made by re-defining the triangle side to share its neighbors opposite vertex. If a better Delauney triangle can be made, the split happens. This process continues until all sides of the parent triangle are considered.

Analysis Outcome

When the analysis is completed the result is an "ordered" list of bathymetry points which define the terrain with increasing accuracy. For example, using the first 100 vertex points,

the terrain might be resolved to within an error of 50 meters. However, using the first 300 points might resolve the terrain to within an error of 1 meter. Depending on the topological accuracy required for current analysis, the user can determine how many points are needed to meet this requirement.

Error Criteria

DOGS uses as its error criterion one of four error definitions to determine subsequent vertex points including: absolute volume, relative volume, absolute height, and relative height. The depth delta parameter, $\Delta\mathbf{h}$, is the absolute difference of the data depth and the triangle surface depth at the given coordinate. The triangle area parameter, **a**, is derived using the two-dimensional projection of the triangle in the x-y plane. The centroid depth parameter, **c**, is the average of the three vertex depths. If the average of the three vertex depths is 0.0, then **c** is assigned the "Minimum Centroid Depth" parameter from the "Triangle Analysis Parameters" dialog. This value is usually set to 1.0. Depending on the terrain it is useful to select the appropriate error criterion for a more accurate analysis. Here are the four error definitions:

Absolute Volume: $(\Delta\mathbf{h} * \mathbf{a}) / 3.0$;

Relative Volume: $(\Delta\mathbf{h} * \mathbf{a}) / (3.0 * \mathbf{c})$;

Absolute Height: $(\Delta\mathbf{h})$;

Relative Height: $(\Delta\mathbf{h} / \mathbf{c})$;

Independent Shoreline Editor/Optimizer

DOGS is equipped with an independent shoreline editor to evaluate a shoreline when bathymetric data is not available or not necessary for the task at hand. This allows for optimizing, cookie cutting, and saving shoreline overlays regardless of bathymetry.

Color Histogram

A color histogram is used to display a selected aspect of the distribution of bathymetric data. The histogram may represent the distribution of depths, depth percents (from 0.0 to 1.0), survey numbers, residual criterion errors, or residual depth errors ($\Delta\mathbf{h}$). The data are drawn with their corresponding bin color. Data drawn in black are not within the range of the histogram. The histogram may be modified by selecting "Histogram Preferences..." from the "View" menu.

Color Contours

To aid in studying the topological terrain, DOGS enables the triangle set to be viewed in color. Depending on the level of resolution, a color is assigned to the triangle based on an average of the three vertex depths. The actual color is determined by referencing the depth to a corresponding histogram bin color.

Tools and Special Functions

Bathymetry/Shoreline Selection Tool

The selection tool may be used to select individual bathymetry points or to select entire shoreline polygons. If you wish to select only bathymetry and not shoreline polygons (or vice versa), choose to hide the overlay that you do not wish to consider in your selection. To toggle the bathymetry view, select "Data Points" from the "View" menu. To toggle the shoreline view, select "Show Overlay" from the "Shoreline" menu.

Special: Holding the SHIFT key down while dragging the mouse enables multiple regions to be selected.

Zoom/Scroll Tools

Zoom and scroll tools are provided to help locate and view specific areas more closely.

Special: Double-clicking on any of these tools reverts back to the original map view.

Shoreline Nudge Tool

The nudge tool may be used to "creep" the entire shoreline or a single shoreline point. This tool is useful when the shoreline is not an exact match to the bathymetry due to instrument or NAD datum differences. The nudge mode is set by selecting "Nudge Mode" from the "Shoreline" menu.

Special: When in the "Entire Shoreline" nudge mode and the nudge tool is selected, the keyboard arrows may be used to creep the shoreline a pixel at a time in the direction of the arrow.

Shoreline Cut Tool

In most cases, shoreline data sets contain information that far exceeds the actual region of interest. In addition, DOGS requires an enclosed water domain in order to compute shoreline triangles. The shoreline cut tool may be used to trace a region (thus becoming the cookie cutter shape) of the shoreline to be cut in a subsequent call to "Cut Overlay...".

Special: Double-clicking on this tool deletes the existing trace polygon.

Special: Holding the SHIFT key down at click time traces the shape of a rectangle.

Shoreline (Water Polygon) Mark Tool

In order to analyze a bathymetry set using a shoreline domain, it is necessary to associate a depth with each shoreline point. For points that represent land segments (islands, beaches, or peninsulas), a user specified value in the "Triangle Analysis Parameters" dialog is assigned to each shoreline point. However, for points that lie across channeled waterways it is necessary for DOGS to use actual depths in that region to conserve the topology and avoid the "shelving" effect which would close the waterway. The Shoreline Mark Tool may be used to indicate which points of the water polygon should be assigned the depth of the closest bathymetry point. A "marked" point is indicated by a small circle drawn around the point.

Special: Double-clicking on this tool clears all marked points.

Special: Holding the SHIFT key down at any time unmarks individual points.

Histogram Bin Check Boxes:

The histogram check boxes may be used to hilight the data related to that bin (the data drawn in that color). Once the data have been hilighted (drawn as large dots), they may be selected independently of the remaining data by choosing "Select Hilighted Points" from the "Analysis" menu.

Menus and Dialogs

The File Menu

Open...

Opens a raw NOS file to be translated, or a DOGS formatted file to be viewed.

Translating an NOS File:

A one degree square NOS bathymetry file may be translated by selecting the file, then selecting the file format and how the data should be parsed out. The data may be saved to 1 file or 10, 20, or 30 minute square files. Choosing the 10 minute square option has a potential yield of 36 files, while the 20 and 30 minute options have potentials of 9 and 4 files, respectively. These options make it possible to save massive amounts of information to several files.

Append...

Appends a DOGS formatted file to an existing document.

Save As...

Saves the current set of non-tossed data points to a specified file.

Save Selection...

Saves the current selection of non-tossed points to a specified file.

Save Vertices...

This menu item allows the ordered list of bathymetry points (vertex points) from the triangle analysis to be saved to a specified file. The number of vertices that will be saved to the file may be modified by selecting "Use First *n* Vertices..." from the "Analysis" menu. To save calculation time in the future, the triangle array may be appended to the vertex points at the end of the file. In this case, all of the vertices will be saved in order to maintain the triangle array integrity, regardless of the number set in the aforementioned dialog.

Save as VERDAT... (CATS)

Saves the shoreline segments used in the triangle analysis along with the ordered vertex points in the VERDAT format for use in the current analysis application "CATS".

Save Vector Contours...

Saves the vector (topological) contours that have been calculated for this triangle optimization to a specified file.

Edit File Header...

This feature may be used to edit the "header" that precedes the bathymetry of a DOGS formatted file. Notes may be added and deleted without having to rely on a separate text editor. A standard file header contains information such as the name of the original raw NOS file from which the current file was translated, the file format, the number of points in the file, the bounding coordinate rectangle of the data set, etc...

The View Menu

Display Preferences...

The display preferences may be modified using the "Display Preferences" dialog. View parameters including: coordinate units, distance units, color contour resolution, weighted contour mesh resolution, shoreline segment drawing option, error plot options, etc., may be changed.

Histogram Preferences...

The "Histogram Preferences" dialog enables the histogram to represent one of several distributions including: Depth Values, Depth Percents, Surveys, Residual Criterion Errors, and Residual Height Errors. The "Max Bin Range" values change as the minimum value, number of bins, and bin increment change. An alert message tells the user if the resulting bin range is less than maximum data value for that distribution. The default values for the distribution may be entered at any time by clicking "Use Default Values".

Reset View...

This menu item sets the current map coordinate boundaries to those of the original view. This task may also be accomplished by double-clicking on the "Zoom In", Zoom Out", and "Scroll" tools.

Reset Map Bounds...

This menu item recalculates the map coordinate boundaries and draws the map according to the new view. It is useful to recalculate the view when a portion of the data has been flagged for removal, or the shoreline has been relocated.

Update Histogram...

When a portion of the data has been flagged for removal choosing this menu item will automatically recalculate the histogram so that it displays an accurate distribution of the remaining data.

Data Points, Triangles, Vertices, Vector, Color, and Weighted Contours

These menu items toggle to hide and show the selected item.

Special: Holding the OPTION key down at click time hides all non-selected view items.

The Analysis Menu

Point Information...

This menu item may be used to view longitude, latitude, depth, index number, survey number, and depth code information for selected bathymetry points. This dialog also enables a data point to be "tossed" out of the data set by clicking in the "Toss" box at the right side of the list. Tossing a point from the data set (referred to as a "flagged point") informs DOGS not to use that point in any way.

Compact Data Set

Compacting the data set is a useful way to get rid of unwanted data points that have been tossed via the "Point Information" dialog. Once the data has been compacted, the tossed points are no longer present in the data set. This menu item is also useful to "crop" bathymetry sets that exceed the area of interest. The compacted file may then be saved at a later time.

Select Hilighted Points

At times it may be helpful to isolate a group of points with similar characteristics, i.e., depth range, survey number, etc... Bathymetry points related to a specific histogram bin may be hilighted by clicking checking the button to the left of the histogram bin. Once the points have been hilighted, choosing "Select Hilighted Points" creates a selection list of those points.

Select Survey Number...

Select Survey Number creates a selected list of bathymetry points recorded from the chosen survey number.

Edit Depth Codes...

Edit Depth Codes is used to calculate a new depth value for a bathymetry point using an overriding depth code chosen from the "Depth Codes" dialog. The "Depth Code Editor" dialog displays the list of selected points. By double-clicking on the "Modified Code" box or clicking the "Edit Code..." button, the list of possible depth codes will be displayed along with information for this point. In this example, point 161307 (the index number indicates which line in the NOS file this data was found), was originally translated using a depth code of 130, or fathoms_10ths. Perhaps the depth code was recorded incorrectly and should have been recorded as 127, or feet_10ths. By selecting a new code it is possible to override the original code to arrive at a different depth.

Generate Triangles...

Error Type: Indicates which error criterion to use for subsequent vertex selection. Select one of four parameters including absolute volume, relative volume, absolute height, and relative height. See "Error Criteria" above for more details.

Error Cutoff: Sets the cutoff limit for the optimization process. The optimization will continue until the specified number of vertices has been reached, until the convergence error is less than the specified value, or until the absolute height error (which may also be the criterion error) is less than the specified value. If none of these criteria are met, i.e., the error never drops below the error indicated or the number of eligible points is less that the number of vertex points entered, the optimization will stop when no more eligible points can be added. In order for a point to be considered "eligible", it must be contained within the specified domain, and it must not be tossed.

Data Domain: Establishes what type of domain will be used in the triangle analysis. If "Shoreline Data" is selected, DOGS will expect a shoreline to be present and an exclusive water domain polygon to have been chosen (if only one water polygon exists, DOGS will automatically use that polygon as the domain). If "Data Hyper-Box" is selected, DOGS will calculate a coordinated box surrounding the data set and assign depths to each corner using a weighted average of the surrounding bathymetry points.

First Point Criterion: This item is relevant only when optimizing a bathymetry set using a hyper-box domain. Once the hyper box has been determined, DOGS must

know how to select the first vertex. By selecting "Data Center-Point", DOGS will use as its first vertex the bathymetry point closest to the center of the hyper-box. By selecting "Surface Deviation", DOGS calculates the three dimensional surface that passes through all four points of the hyper-box, then takes as its first vertex the point farthest from that surface.

Progress Option: The optimization progress may be indicated by a progress box or by drawing the triangles as they are created and updated.

Default Shoreline Depth: This depth value is relevant when using a shoreline set as the data domain. When the initial shoreline triangles are determined, the default depth is assign to each "unmarked" boundary segment point (See "Shoreline Mark Tool" above). To avoid a contour "lip", this value should be less that the most shallow bathymetry point. **Note:** The zero datum is Mean Lower Low Water. Bathymetry above this datum have negative values.

Minimum Centroid Depth: This value is used only if relative volume or relative height has been selected as the error criterion. The relative errors are derived from the absolute errors by simply dividing by the depth at the centroid of the triangle. Since depths may be positive and negative, it is possible to encounter a centroid depth of zero. This would make division impossible. To avoid this situation, the minimum centroid depth is used in place of zero.

Dispose Triangles...

Disposes the current triangle set along with all triangle dependent items such as vector contours, error plot windows, vertex point list, etc...

Resolve Channel Triangles

Criterion Error Plot / Absolute Height Error Plot

The error plots may be used to evaluate the "Error vs. Vertex" curve when it is important to know how the error term behaved during the optimization, or to know if the terrain was resolved beyond the desired limit. This information may be used when saving a select number of vertices to a file (see "Use First *n* Vertices..." below).

Special: Dragging the mouse (in the grid rectangle) from the vertex start point to the vertex end point zooms into the plot. Double-clicking anywhere in the grid rectangle resets the plot boundaries.

Use First *n* Vertices...

A number of vertices less than the number calculated may be saved to a file when calling "Save Vertices..." from the "File" menu (when not appending the triangle array). This item works well in conjunction with the error plots to determine the vertex at which the desired resolution is reached. For example, if 500 points resolved the terrain to 1 meter (the resolution desired), and a total of 10000 points were used as vertices, entering 500 as the vertex cutoff would allow only the first 500 vertices to be saved.

Create Vector Contours...

Calculates topological contour lines based on an optimized bathymetry set.

Dispose Vector Contours

Disposes the current set of vector contours.

Create Weighted Contours

An added feature to DOGS is the weighted contour grid. The weighted color contours are based on a either a 5x5, 10x10, 15x15, or 20x20 imaginary grid that is set over the data. The depth at each point of intersection is arrived at by taking the weighted average of the closest bathymetry points. Keep in mind that this contour analysis is simply a graphical representation of the terrain and does not consider shoreline topology, but is helpful in screening "outliers" in the data set before performing the triangle analysis. The contour color is determined as described in "Color Contours".

Dispose Weighted Contours

Disposes the current set of weighted contours.

Sample X,Y Points...

Sample X,Y Points is used to interpolate depths for the given set of x,y points. Once a triangle set has been calculated, this function may be used to "sift" the x,y points through the triangle list to return a set of x,y,z points. The X,Y file takes as its arguments a longitude value, then a latitude value separated by a comma. Both of these values must be in decimal degrees with a return character at the end of each line. Keep in mind that West longitudes must be preceded by a minus (-) sign. The resultant depth is reported in **meters**.

The Shoreline Menu

Load Overlay...

Use this menu item to view a BNA shoreline file. A shoreline may be merged with an existing bathymetry set, or opened in a separate window. If a shoreline has already been merged with a bathymetry set, a subsequent merge with another shoreline file

automatically disposes the previously merged overlay. Note that a shoreline file may not be merged with another shoreline file.

Dispose Overlay

Use this menu item to dispose the current shoreline overlay. If the shoreline was merged with a bathymetry set, the bathymetry window remains in tact.

Reset Overlay

Show Overlay

Select to show or hide the shoreline overlay. When the overlay is not visible, it is not possible to select shoreline polygons or to use the shoreline tools. If you choose to hide the overlay and a portion of the shoreline is selected, the selection list will be automatically disposed.

Optimize Shoreline...

The optimizer is able to perform three independent operations on a shoreline data set. If more than one optimization procedure is checked, the operations will be performed in the order in which they appear in the dialog. In this example, the shoreline will be enhanced, BB optimized, then Delta-Epsilon optimized. Here is a more detailed description of the optimizations and their parameters:

Enhance Shoreline: This feature ensures that consecutive points on the shoreline are not located more than the specified distance, **d**, say 500 meters, from each other. For example, if point **B** is 2000 meters from point **A**, the enhancer will continue to add

points at a distance **d** between **A** and **B** until the distance between the last point added and **B** is at least **d**. In the case where the distance between **A** and **B** is less than twice **d**, a point will be added midway between **A** and **B**. In general, the shoreline should be enhanced before performing the Rolling BB or Delta-Epsilon optimizations.

Rolling BB: The rolling BB optimization helps to reduce the "jaggedness" of a shoreline due to piers, river inlets, etc... The rolling BB optimization takes three consecutive shoreline points, **A**, **B**, and **C**, then compares the radius of the BB to the radius of the circle formed by **A**, **B**, and **C**. If the radius of **A**, **B**, and **C** is smaller than that of the BB, or the angle formed by **AB** and **BC** is acute, the mid point **B** is removed and the algorithm continues.

Delta-Epsilon: The Delta test allows shoreline points to be removed if they are closer to each other than the maximum allowed spacing **delta**. It ensures that, given points **A**, **B**, and **C**, if **B** is removed, the distance between **A** and **C** will not be greater than **delta**. The Epsilon test allows points to be removed if the perpendicular line drawn from point **B** to segment/line **AC** is within the distance **epsilon**. This perpendicular distance check helps to maintain the overall shape of the shoreline. Both the Delta and Epsilon criteria must be satisfied in order to remove a point using this optimization.

Group Polygons

Group Polygons is enabled when two and only two polygons are selected. Two polygons can be grouped by taking their union (if they overlap each other), or by simply connecting the closest points from each polygon. At times it is useful to group polygons if their segments cross, or if a channel between them is to narrow to be resolved.

Note: If the "Closest Point Method" grouping is performed on a pair of polygons, it MUST be followed by another optimization that resolves the connecting line segment BEFORE attempting to triangulate the data set.

Shoreline Nudge Mode

The nudge mode works in conjunction with the shoreline nudge tool to physically relocate the shoreline data independent of the bathymetry. To relocated the entire shoreline, select "Entire Shoreline" from the menu. To move individual points on a the shoreline, select "Single Point" for the nudge mode. **Note**, once the shoreline has been nudged in the "Entire Shoreline" mode, the original shoreline point positions can not be recovered by "Reset Overlay".

Set Exclusive Domain...

DOGS requires that an exclusive water domain polygon be established before calculating shoreline triangles. If only one water polygon (the polygon points follow in counter-clockwise order) is included in the list, DOGS will select it automatically. Selecting the exclusive domain temporarily deletes (sets the shoreline point flags to not use) ALL other water polygons, ALL polygons outside of the domain polygon, and all land-in-land polygons inside of the domain. The deleted polygons may be recovered by choosing "Reset Overlay" from the "Shoreline" menu.

Delete Non-Domain Data

Deletes all bathymetry data outside of the exclusive domain polygon.

Cut Overlay...

Cut Overlay enables a specified region of the shoreline to be extracted from the shoreline data set and saved to a specified file. The region is determined by using the trace tool (see "Shoreline Cut Tool" above) to draw an outline of an enclosed polygon or by using the bounding rectangle of the bathymetry set (the hyper-box). There are two modes in which to cut an overlay. One mode **(1)** uses the traced region (or boxed region) as an enclosing water domain, taking the difference of each polygon it encounters. To cut in this mode, check the "Use As Enclosing Water Domain" box. The other mode **(2)** takes the intersection of each shoreline polygon with the specified region. Make sure that the aforementioned box is NOT checked. A save file name must be specified by clicking "Save As...". This file may be automatically loaded by checking "Auto-Load Save File".

Here are examples of both cut modes (1) and (2) given the following shoreline and traced region:

(1) (2)

Save Overlay...

Saves the current overlay to a specified file, "as is", with all enhancements, optimizations, and nudges.

Appendix 4 :

Data Transformation Program

This program transforms the data from the output format from DOGS to the input format for ARC/INFO for the contour lines. It is written in Turbo Pascal for the PC.

```
program Transform;
{ This program asks for the name of a file to transform from the DOGS
format into the format acceptable to Arc/Info. It then transforms that file
and asks for another one. When the user hits return at the prompt, the
program ends.
Created by : Michele L.G. Lyons, under contract to Larry Jacobsen
at the Southwest Fisheries Science Center, La Jolla, CA November 5, 1996

It reads in the input file one line at a time, then reads it out to the
output file mildly changed in format.

11/13/96 ARC/INFO does not require unique id numbers. All headers should be 1.

Will only work for files output from DOGS 6.0.2 from Jerry Gault, HazMat,
Seattle. Because of the input routines (ReadHeader and ReadSite), this
program requires the lines be from -100 to -180 longitude and from 10 to
90 latitude.

var EndOfProgram : indicator that the user wants to end the program
   EnterFile : indicator of reading file of file names to transform
   Id : the unique id number for each of the lines created
   InputData : the input file
   OutputData : the output file
   CommandData : the file of file names to be transformed
}

var EndOfProgram, EnterFile : Boolean;
   Id : LongInt;
   CommandData, InputData, OutputData : text;

procedure Initialization;
{ This procedure initializes the global variables.
var Answer : user's answer to query about entering file names in file
calls : nothing
```

```
called by : main
}
var Answer : string;

begin

    EndOfProgram := FALSE;

    { initialize the unique id number }
{    writeln;}
{    write('What is the next number for the id value? ');}
{    readln(Id);}
     Id := 1;

    { initialize whether or not they enter the file names by hand or in
    one file }
    writeln;
    write('Do you want to enter the file names in a file? ');
    readln(Answer);
    EnterFile := ((Answer[1] = 'y') or (Answer[1] = 'Y'));

end; { Initialization }

procedure OpenFile(Name : String; RW : Boolean; var FilePtr : Text);
{ This procedure opens a file, either read or write, to process.
procedures : Name : name of file
         RW : if true, read, else write
         FilePtr : the file to open
called by : AskFileName, AskOutputFile, OpenCommandFile, RunFile
calls : none
}
begin
    assign(FilePtr, Name);
    if RW then reset(FilePtr) else rewrite(FilePtr);
end; { OpenFile }

procedure OpenCommandFile;
{ This procedure asks for the name of the command file.
var CommandFile : name of the command file
called by : RunFile
calls : OpenFile
}
```

```
var CommandFile : string;

begin
    write('What is the command file name? ');
    readln(CommandFile);
    OpenFile(CommandFile, TRUE, CommandData);
end; { OpenCommandFile }

procedure AskFileName;
{ This procedure asks for the name of the input file.
var InputFile : name of the input file
called by : main
calls : OpenFile
}
var InputFile : string;

begin
    write('What is the input file name? ');
    readln(InputFile);
    OpenFile(InputFile, TRUE, InputData);
end; { AskFileName }

procedure AskOutputFile;
{ This procedure opens the file for output.
var OutputFile : name of the output file
calls : OpenFile
called by : main
}
var OutputFile : string;

begin
    write('What is the output file name? ');
    readln(OutputFile);
    OpenFile(OutputFile, FALSE, OutputData);
end; { AskOutputFile }

procedure ReadHeader(var dep : integer);
{ This procedure reads the header data for the regular data for the contour
lines.
var a, b, c : input characters to turn into numbers
   x : the integer that is the output
param dep : the integer read from the header
```

```
calls : none
called by : Transforming
}
var a, b, c : char;
   x : integer;
begin

    readln(InputData, a, b, c);
    if b = '.' then
    begin
        x := (integer(a)-48);
    end else if c = '.' then
    begin
        x := (integer(a)-48)*10 + (integer(b)-48);
    end else
    begin
        x := (integer(a)-48)*100 + (integer(b)-48)*10 + (integer(c)-48);
    end;
    dep := -x;

end; { ReadHeader }

procedure ReadSite(var long, lat : real; var EndOfLine : Boolean);
{ This procedure reads the rest of the data attached to the header of the
contour line.
var test : test character to determine if it's a header or a record
   a : for loop counter
   b .. j : input data from the file
   site : string read in from file
   trash : garbage stuff read in from input file
param long : output data from file
     lat : output data from file
     EndOfLine : true at end of record, else false
calls : none
called by : Transforming
}
var test : char;
   a : integer;
   b, c, d, e, f, g, h, i, j : real;
   site, trash : string;

begin
```

```
    read(InputData, test);
    if test = '-' then
    begin
        for a := 1 to 20 do
        begin
            read(InputData, site[a]);
        end;

        b := (integer(site[1])-48) * 100;
        c := (integer(site[2])-48) * 10;
        d := (integer(site[3])-48);
        e := (integer(site[5])-48) / 10;
        f := (integer(site[6])-48) / 100;
        g := (integer(site[7])-48) / 1000;
        h := (integer(site[8])-48) / 10000;
        i := (integer(site[9])-48) / 100000;
        j := (integer(site[10])-48) / 1000000;
        long := 0 - b - c - d - e - f - g - h - i - j;

        b := (integer(site[12])-48) * 10;
        c := (integer(site[13])-48);
        d := (integer(site[15])-48) / 10;
        e := (integer(site[16])-48) / 100;
        f := (integer(site[17])-48) / 1000;
        g := (integer(site[18])-48) / 10000;
        h := (integer(site[19])-48) / 100000;
        i := (integer(site[20])-48) / 1000000;
        lat := b + c + d + e + f + g + h + i;

        readln(InputData, trash);
    end { - } else EndOfLine := TRUE;
end; { ReadSite }

procedure WriteHeader;
{ This procedure writes the new type header.
calls : none
called by : Transforming
}
begin
    writeln(OutputData, Id);
end; { WriteHeader }
```

```
procedure WriteSite(lat, long : real; dep : integer);
{ This procedure writes the data read in from the input file to the
output file.
param : lat, long, dep : information for output file
calls : none
called by : Transforming
}
begin
    writeln(OutputData, lat, ',', long, ',', dep);
end; { WriteSite }

procedure WriteFooter;
{ This procedure writes the end of the record into the output file.
calls : none
called by : Transforming
}
begin
    writeln(OutputData, 'end');
end; { WriteFooter }

procedure Transforming;
{ The procedure transforms the data from the input file into the format
acceptable by the GIS.
var long, lat, dep : data read from input to output file
   trash : character of unnecessary input
   EndOfList : record of the end of list if true
calls : ReadHeader, WriteHeader, WriteSite, ReadSite, WriteFooter
called by : main, RunFile
}
var long, lat : real;
   trash : char;
   dep : integer;
   EndOfList : Boolean;

begin
    { read the first character - which will be " - in and get rid of it. }
    read(InputData, trash);

    { loop to read and process the whole file }
    while not eof(InputData) do
    begin
        { read the header of the set of lines }
```

```
        ReadHeader(dep);
        WriteHeader;

        EndOfList := FALSE;
        { read the first line of the lat-long list }
        ReadSite(long, lat, EndOfList);

        while (not eof(InputData)) and (not EndOfList) do
        begin

            { read the rest of the list, one site at a time }
            WriteSite(long, lat, dep);
            ReadSite(long, lat, EndOfList);

        end; { while }

        { write the end of the set }
        WriteFooter;
        { increment the id number }
{       Id := Id + 1;}
    end;

    { write the end of output file }
    WriteFooter;

end; { Transforming }

procedure CleanUp;
{ This procedure cleans up the variables used in one loop.
calls : none
called by : main, RunFile
}
var Answer : string;

begin
    close(InputData);
    close(OutputData);
end; { CleanUp }

procedure Continue;
{ This procedure asks the user whether they want to continue.
var Answer : continue indicator
```

```
calls : none
called by : main
}
var Answer : string;

begin

    { initialize the doing another file query }
    writeln;
    write('Do you wish to do another file? ');
    readln(Answer);
    EndOfProgram := ((Answer[1] = 'n') or (Answer[1] = 'N'));

end; { Continue }

procedure RunFile;
{ This procedure runs the program using file names out of a file, instead
of having them input by the user one at a time.
var OutputFile : name of output file
   InputFile : name of input file
calls : OpenCommandFile, AskInputFile, AskOutputFile, Transforming,
     CleanUp
called by : main
}
var OutputFile, InputFile : string;

begin
writeln('in runfile');
    OpenCommandFile;
    while not eof(CommandData) do
    begin
        readln(CommandData, InputFile);
        OpenFile(InputFile, TRUE, InputData);

        readln(CommandData, OutputFile);
        OpenFile(OutputFile, FALSE, OutputData);

        Transforming;
        CleanUp;
    end;
end; { RunFile }
```

```
{ calls : Initialization, AskFileName, AskOutputFile, Transforming,
  CleanUp, Continue, RunFile }
begin { main }

    Initialization;

    { This loop controls the asking for more files. }
    While not EndOfProgram do
    begin

        if EnterFile then RunFile else
        begin
            { The following procedure asks for the file name and opens
            the file, printing out an error message if the file
            does not exist. }
            AskFileName;
            { The following procedure asks for and opens the output file }
            AskOutputFile;
            { This procedure transforms the data from one format to another. }
            Transforming;
            { This file closes all files and asks if user wants to continue. }
            CleanUp;
        end;

        Continue;
    end;

    writeln;
    writeln('The last id used was ', Id, '.');
    writeln('See you later.');
end. { main }
```

Appendix 5 :

Transform Surface Data File

These are the changes to the previous program to translate the surface overlay values into a form that ARC/INFO will accept.

```
program TransformSurface;
{ This program asks for the name of a file to transform from the DOGS
format for the shoreline into the format acceptable to Arc/Info.  It
then transforms that file and asks for another one.  When the user hits
return at the prompt, the program ends.
Created by : Michele L.G. Lyons, under contract to Larry Jacobsen
at the Southwest Fisheries Science Center, La Jolla, CA November 5, 1996

It reads in the input file one line at a time, then reads it out to the
output file mildly changed in format.

11/13/96 ID is not unique.  Is constant at 2.

Will only work for shoreline files output from DOGS 6.0.2 from Jerry Gault,
HazMat, Seattle.  Because of the input routines (ReadHeader and ReadSite), this
program requires the lines be from -100 to -180 longitude and from 10 to
90 latitude.

var EndOfProgram : indicator that the user wants to end the program
   EnterFile : indicator of reading file of file names to transform
   Id : the unique id number for each of the lines created
   InputData : the input file
   OutputData : the output file
   CommandData : the file of file names to be transformed
}

var EndOfProgram, EnterFile : Boolean;
   Id : LongInt;
   CommandData, InputData, OutputData : text;

procedure Initialization;
{ This procedure initializes the global variables.
```

```
var Answer : user's answer to query about entering file names in file
calls : nothing
called by : main
}
var Answer : string;

begin

    EndOfProgram := FALSE;

    { initialize the unique id number }
{    writeln;}
{    write('What is the next number for the id value? ');}
{    readln(Id);                                    }
     Id := 6;

    { initialize whether or not they enter the file names by hand or in
    one file }
    writeln;
    write('Do you want to enter the file names in a file? ');
    readln(Answer);
    EnterFile := ((Answer[1] = 'y') or (Answer[1] = 'Y'));

end; { Initialization }

procedure WriteSite(lat, long : real; dep : integer);
{ This procedure writes the data read in from the input file to the
output file.
param : lat, long, dep : information for output file
calls : none
called by : Transforming
}
begin
    writeln(OutputData, lat, ',', long, ',', 0);
end; { WriteSite }
```

Appendix 6 : Sample from file of soundings data

This appendix is a sample of soundings data from a modified NODC file ready to be input into ARC/INFO.

```
1,-117.157222,32.064000,-901.598400,-0.000000,-0.000000,-6121
1,-117.099350,32.082478,-486.460800,-0.000000,-0.000000,-6121
1,-117.114783,32.077725,-687.628800,-0.000000,-0.000000,-6121
1,-117.106594,32.080847,-596.188800,-0.000000,-0.000000,-6121
1,-117.124714,32.074583,-601.675200,-0.000000,-0.000000,-6121
1,-117.131508,32.072314,-554.126400,-0.000000,-0.000000,-6121
1,-117.144061,32.068019,-614.476800,-0.000000,-0.000000,-6121
1,-117.137753,32.070153,-568.756800,-0.000000,-0.000000,-6121
1,-117.077794,32.090683,-149.961600,-0.000000,-0.000000,-6121
end
```

Appendix 7 : Sample from file of shoreline

This appendix contains a sample file of a coastline ready to be input into ARC/INFO.

```
6.00E+00
-1.18E+02,3.3E+01,0
-1.18E+02,3.2E+01,0
-1.17E+02,3.2E+01,0
-1.17E+02,3.24997680E+01,0
-1.17128571E+02,3.25000760E+01,0
-1.17128281E+02,3.25030330E+01,0
-1.17274483E+02,3.29924930E+01,0
-1.17275284E+02,3.29954800E+01,0
-1.17276291E+02,3.29982950E+01,0
-1.17277878E+02,3.3E+01,0
-1.18E+02,3.3E+01,0
end,,
end,,
```

Appendix 8 : Sample from file of island

This appendix contains a sample file of an island ready to be input into ARC/INFO.

```
8.00E+00
-1.17241020E+02,3.23892860E+01,0
-1.17241501E+02,3.23893130E+01,0
-1.17241966E+02,3.23901140E+01,0
-1.17250702E+02,3.24176520E+01,0
-1.17250778E+02,3.24182550E+01,0
-1.17250153E+02,3.24186860E+01,0
-1.17248253E+02,3.24190860E+01,0
-1.17247711E+02,3.24189680E+01,0
-1.17246902E+02,3.24183920E+01,0
-1.17239578E+02,3.23963320E+01,0
-1.17240013E+02,3.23942220E+01,0
-1.17239670E+02,3.23933720E+01,0
-1.17240891E+02,3.23905070E+01,0
-1.17241020E+02,3.23892860E+01,0
end,,
end,,
```

Appendix 9:
Comparison of Default Weed Parameter to Zero

This appendix contains measures of area at each depth for several of the degree blocks off the Calfornia coast for the normal default weed parameter and with weed = 0. This presents the type of information that can be extracted from the edited soundings data by ARC/INFO.

depth (m)	default weed area (m^2)	weed = 0 area (m^2)	difference (m^2)
32 117			
100	8.17E+06	8.17E+06	-4
99	8.33E+06	8.33E+06	0
98	8.70E+06	8.70E+06	128
97	8.96E+06	8.96E+06	130
96	9.80E+06	9.80E+06	126
95	9.06E+06	9.06E+06	4
94	9.22E+06	9.22E+06	258
93	9.39E+06	9.39E+06	126
92	1.00E+07	1.00E+07	0
91	1.01E+07	1.01E+07	140
90	1.01E+07	1.01E+07	280
89	1.06E+07	1.06E+07	-12
88	1.06E+07	1.06E+07	232
87	1.08E+07	1.08E+07	80
86	1.09E+07	1.09E+07	120
85	1.12E+07	1.12E+07	300
84	1.09E+07	1.09E+07	208
83	1.05E+07	1.05E+07	40
82	1.06E+07	1.06E+07	284
81	1.07E+07	1.07E+07	120
80	1.06E+07	1.06E+07	220
79	1.07E+07	1.06E+07	236
78	1.05E+07	1.05E+07	124
77	1.05E+07	1.05E+07	260
76	1.05E+07	1.05E+07	236
75	1.02E+07	1.02E+07	292
74	1.05E+07	1.05E+07	252
73	1.04E+07	1.04E+07	300
72	1.05E+07	1.05E+07	232

71	1.06E+07	1.06E+07	288
70	1.08E+07	1.08E+07	92
69	1.07E+07	1.07E+07	376
68	1.09E+07	1.09E+07	276
67	1.07E+07	1.07E+07	288
66	1.10E+07	1.10E+07	404
65	1.17E+07	1.17E+07	104
64	1.16E+07	1.16E+07	352
63	1.19E+07	1.19E+07	268
62	1.20E+07	1.20E+07	416
61	1.22E+07	1.22E+07	264
60	1.21E+07	1.21E+07	404
59	1.24E+07	1.24E+07	308
58	1.27E+07	1.27E+07	280
57	1.26E+07	1.26E+07	392
56	1.28E+07	1.27E+07	296
55	1.26E+07	1.26E+07	352
54	1.28E+07	1.28E+07	392
53	1.27E+07	1.27E+07	360
52	1.29E+07	1.29E+07	364
51	1.28E+07	1.28E+07	380
50	1.30E+07	1.30E+07	464
49	1.30E+07	1.30E+07	288
48	1.31E+07	1.31E+07	484
47	1.32E+07	1.32E+07	404
46	1.37E+07	1.37E+07	416
45	1.41E+07	1.41E+07	412
44	1.43E+07	1.43E+07	380
43	1.37E+07	1.37E+07	460
42	1.40E+07	1.40E+07	352
41	1.41E+07	1.41E+07	496
40	1.36E+07	1.36E+07	388
39	1.41E+07	1.41E+07	468
38	1.47E+07	1.47E+07	472
37	1.50E+07	1.50E+07	456
36	1.51E+07	1.51E+07	392
35	1.57E+07	1.57E+07	468
34	1.49E+07	1.49E+07	368
33	1.51E+07	1.51E+07	444
32	1.50E+07	1.50E+07	428
31	1.52E+07	1.52E+07	480
30	1.55E+07	1.55E+07	496

29	1.57E+07	1.57E+07	428
28	1.66E+07	1.66E+07	416
27	1.66E+07	1.66E+07	404
26	1.76E+07	1.76E+07	336
25	1.71E+07	1.71E+07	324
24	1.79E+07	1.79E+07	340
23	1.74E+07	1.74E+07	248
22	1.92E+07	1.92E+07	192
21	1.96E+07	1.96E+07	180
20	2.02E+07	2.02E+07	-2320
19	2.09E+07	2.09E+07	-5564
18	2.18E+07	2.18E+07	-3436
17	2.25E+07	2.25E+07	-1272
16	2.37E+07	2.37E+07	920
15	2.44E+07	2.44E+07	3352
14	2.43E+07	2.43E+07	5916
13	2.32E+07	2.32E+07	7888
12	2.14E+07	2.14E+07	9536
11	2.11E+07	2.11E+07	13700
10	2.14E+07	2.13E+07	25550
9	2.16E+07	2.16E+07	40920
8	2.14E+07	2.14E+07	36040
7	2.21E+07	2.21E+07	34200
6	1.99E+07	1.98E+07	18360
5	1.97E+07	1.96E+07	21530
4	2.86E+07	2.85E+07	37280
3	2.47E+07	2.47E+07	49940
2	2.40E+07	2.40E+07	61850
1	2.78E+07	2.77E+07	46660
0	3.63E+07	3.66E+07	-369500

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100	4.14E+06	4.14E+06	1024
99	4.46E+06	4.46E+06	4480
98	4.46E+06	4.46E+06	5244
97	4.92E+06	4.92E+06	2300
96	5.32E+06	5.31E+06	5378
95	5.35E+06	5.34E+06	6652
94	6.37E+06	6.36E+06	7936
93	5.85E+06	5.84E+06	8706
92	6.38E+06	6.37E+06	8060

91	6.05E+06	6.04E+06	9086
90	6.69E+06	6.69E+06	8192
89	6.09E+06	6.08E+06	6912
88	6.90E+06	6.90E+06	6398
87	7.12E+06	7.11E+06	6468
86	7.90E+06	7.90E+06	4482
85	8.14E+06	8.14E+06	4478
84	7.11E+06	7.11E+06	4540
83	8.95E+06	8.95E+06	4480
82	7.34E+06	7.34E+06	4478
81	8.36E+06	8.35E+06	4604
80	8.37E+06	8.37E+06	4480
79	1.10E+07	1.09E+07	4580
78	9.36E+06	9.35E+06	4800
77	9.60E+06	9.60E+06	5698
76	1.02E+07	1.02E+07	5696
75	9.47E+06	9.46E+06	5758
74	9.45E+06	9.45E+06	5564
73	7.13E+06	7.13E+06	6080
72	7.68E+06	7.67E+06	7356
71	6.59E+06	6.58E+06	7682
70	7.10E+06	7.09E+06	7356
69	6.54E+06	6.53E+06	7298
68	7.29E+06	7.28E+06	6972
67	6.97E+06	6.96E+06	6908
66	7.35E+06	7.34E+06	6658
65	7.78E+06	7.78E+06	6528
64	7.78E+06	7.78E+06	-1342
63	8.74E+06	8.76E+06	-25090
62	8.63E+06	8.66E+06	-27330
61	9.93E+06	9.97E+06	-37820
60	9.08E+06	9.11E+06	-28990
59	1.10E+07	1.10E+07	-18180
58	9.54E+06	9.55E+06	-14720
57	1.02E+07	1.02E+07	-8280
56	7.73E+06	7.74E+06	-5756
55	8.47E+06	8.47E+06	-6078
54	9.76E+06	9.77E+06	-7108
53	8.14E+06	8.15E+06	-12290
52	1.01E+07	1.01E+07	-5408
51	8.43E+06	8.42E+06	7484
50	1.01E+07	1.01E+07	7836

49	8.29E+06	8.29E+06	7880
48	1.03E+07	1.03E+07	7580
47	9.12E+06	9.11E+06	7512
46	1.04E+07	1.04E+07	7908
45	1.01E+07	1.01E+07	8012
44	9.34E+06	9.33E+06	7514
43	1.06E+07	1.06E+07	7332
42	8.07E+06	8.06E+06	8528
41	1.03E+07	1.03E+07	4512
40	8.03E+06	8.02E+06	2640
39	8.81E+06	8.81E+06	3780
38	7.98E+06	7.98E+06	-1284
37	8.90E+06	8.90E+06	-3328
36	8.48E+06	8.45E+06	9588
35	9.08E+06	9.05E+06	8124
34	9.79E+06	9.78E+06	8088
33	9.38E+06	9.35E+06	7996
32	1.24E+07	1.24E+07	8280
31	1.16E+07	1.16E+07	9820
30	1.39E+07	1.39E+07	9380
29	1.22E+07	1.22E+07	9240
28	1.71E+07	1.71E+07	9132
27	1.39E+07	1.39E+07	8848
26	1.54E+07	1.54E+07	8228
25	1.81E+07	1.80E+07	7800
24	2.02E+07	2.02E+07	6748
23	1.90E+07	1.90E+07	8188
22	1.48E+07	1.48E+07	7504
21	1.79E+07	1.79E+07	4960
20	1.44E+07	1.44E+07	2960
19	1.50E+07	1.50E+07	6044
18	1.48E+07	1.47E+07	5740
17	1.38E+07	1.38E+07	8396
16	1.31E+07	1.31E+07	8848
15	1.38E+07	1.38E+07	7152
14	1.24E+07	1.24E+07	-1112
13	1.47E+07	1.47E+07	11560
12	1.40E+07	1.40E+07	14570
11	1.30E+07	1.29E+07	18530
10	1.28E+07	1.28E+07	32240
9	1.28E+07	1.28E+07	32300
8	1.25E+07	1.24E+07	37000

7	1.17E+07	1.17E+07	58500
6	1.13E+07	1.12E+07	55580
5	1.24E+07	1.24E+07	25460
4	1.66E+07	1.66E+07	42690
3	2.69E+07	2.69E+07	5892
2	4.66E+07	4.66E+07	-35990
1	7.68E+07	7.68E+07	-62230
0	3.34E+07	3.36E+07	-183000

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100	6.40E+06	6.40E+06	62
99	7.61E+06	7.61E+06	-2
98	6.47E+06	6.47E+06	-66
97	6.38E+06	6.38E+06	68
96	6.33E+06	6.33E+06	-4
95	6.05E+06	6.05E+06	2
94	7.04E+06	7.04E+06	4
93	7.23E+06	7.23E+06	-2
92	8.67E+06	8.67E+06	-68
91	7.65E+06	7.65E+06	60
90	7.97E+06	7.97E+06	0
89	7.75E+06	7.75E+06	-68
88	8.59E+06	8.59E+06	68
87	8.29E+06	8.29E+06	-2
86	7.57E+06	7.57E+06	4
85	7.16E+06	7.16E+06	-62
84	6.43E+06	6.43E+06	64
83	6.94E+06	6.94E+06	-62
82	6.71E+06	6.71E+06	-4
81	7.47E+06	7.47E+06	4
80	7.69E+06	7.69E+06	62
79	7.86E+06	7.86E+06	-4
78	7.47E+06	7.47E+06	-4
77	7.82E+06	7.82E+06	-2
76	7.92E+06	7.92E+06	-62
75	8.73E+06	8.73E+06	68
74	8.71E+06	8.71E+06	0
73	7.81E+06	7.81E+06	2
72	7.93E+06	7.93E+06	-62
71	7.53E+06	7.53E+06	68
70	8.42E+06	8.42E+06	-68

69	7.87E+06	7.87E+06	62
68	8.55E+06	8.55E+06	-64
67	7.65E+06	7.65E+06	28
66	8.51E+06	8.51E+06	-2
65	8.08E+06	8.08E+06	2
64	7.48E+06	7.48E+06	4
63	7.99E+06	7.99E+06	0
62	7.40E+06	7.40E+06	-28
61	7.42E+06	7.42E+06	34
60	7.06E+06	7.06E+06	-30
59	7.07E+06	7.07E+06	36
58	6.61E+06	6.61E+06	-30
57	6.76E+06	6.76E+06	0
56	6.72E+06	6.72E+06	30
55	7.14E+06	7.14E+06	-28
54	7.27E+06	7.27E+06	-4
53	6.99E+06	6.99E+06	0
52	7.30E+06	7.30E+06	0
51	6.77E+06	6.77E+06	-4
50	7.18E+06	7.18E+06	-4
49	6.90E+06	6.90E+06	-4
48	7.26E+06	7.26E+06	0
47	6.41E+06	6.41E+06	-2
46	6.64E+06	6.64E+06	0
45	6.28E+06	6.28E+06	-30
44	6.64E+06	6.64E+06	32
43	6.71E+06	6.71E+06	2
42	5.76E+06	5.76E+06	258
41	5.61E+06	5.61E+06	708
40	4.57E+06	4.57E+06	770
39	4.39E+06	4.39E+06	544
38	2.32E+06	2.32E+06	388
37	2.30E+06	2.30E+06	224
36	2.40E+06	2.40E+06	-2
35	7.62E+06	7.62E+06	-62
34	6.68E+06	6.68E+06	-62
33	9.57E+06	9.57E+06	-100
32	1.06E+07	1.06E+07	-104
31	7.68E+06	7.68E+06	66
30	1.10E+07	1.10E+07	28
29	8.34E+06	8.34E+06	126
28	1.24E+07	1.24E+07	80

27	8.29E+06	8.29E+06	60
26	1.24E+07	1.24E+07	52
25	8.04E+06	8.04E+06	28
24	1.27E+07	1.27E+07	28
23	7.67E+06	7.67E+06	20
22	1.38E+07	1.38E+07	136
21	1.25E+07	1.25E+07	252
20	1.14E+07	1.14E+07	784
19	1.13E+07	1.13E+07	1068
18	1.11E+07	1.11E+07	748
17	1.08E+07	1.08E+07	560
16	9.78E+06	9.78E+06	1230
15	9.96E+06	9.96E+06	1404
14	1.01E+07	1.01E+07	896
13	1.01E+07	1.01E+07	136
12	9.92E+06	9.92E+06	402
11	8.77E+06	8.77E+06	1284
10	8.55E+06	8.54E+06	3112
9	7.44E+06	7.43E+06	3916
8	6.73E+06	6.72E+06	4026
7	5.86E+06	5.85E+06	9320
6	5.15E+06	5.13E+06	15710
5	4.89E+06	4.87E+06	20930
4	5.23E+06	5.21E+06	22160
3	5.58E+06	5.56E+06	20380
2	5.88E+06	5.84E+06	41330
1	1.02E+07	9.84E+06	360300
0	1.74E+07	1.79E+07	-526600

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100	6.84E+06	6.84E+06	-2
99	7.53E+06	7.53E+06	-2
98	7.37E+06	7.37E+06	0
97	6.81E+06	6.81E+06	0
96	6.75E+06	6.75E+06	-2
95	6.75E+06	6.75E+06	2
94	7.26E+06	7.26E+06	-4
93	7.14E+06	7.14E+06	4
92	6.88E+06	6.88E+06	-4
91	6.60E+06	6.60E+06	-4
90	6.45E+06	6.45E+06	-2

89	6.34E+06	6.34E+06	-2
88	6.29E+06	6.29E+06	2
87	6.28E+06	6.28E+06	-2
86	6.18E+06	6.18E+06	4
85	6.19E+06	6.19E+06	-2
84	6.23E+06	6.23E+06	0
83	6.31E+06	6.31E+06	2
82	6.13E+06	6.13E+06	-4
81	6.16E+06	6.16E+06	4
80	6.18E+06	6.18E+06	4
79	6.08E+06	6.08E+06	0
78	6.01E+06	6.01E+06	-2
77	6.01E+06	6.01E+06	-4
76	6.03E+06	6.03E+06	2
75	6.14E+06	6.14E+06	-2
74	6.12E+06	6.12E+06	-2
73	6.13E+06	6.13E+06	-4
72	6.16E+06	6.16E+06	-4
71	6.17E+06	6.17E+06	-4
70	6.20E+06	6.20E+06	2
69	6.18E+06	6.18E+06	2
68	6.25E+06	6.25E+06	4
67	6.19E+06	6.19E+06	4
66	6.29E+06	6.29E+06	-2
65	6.31E+06	6.31E+06	-2
64	6.25E+06	6.25E+06	-2
63	6.22E+06	6.22E+06	-4
62	6.21E+06	6.21E+06	4
61	6.35E+06	6.35E+06	-2
60	6.30E+06	6.30E+06	-4
59	6.45E+06	6.45E+06	-2
58	6.23E+06	6.23E+06	-4
57	6.49E+06	6.49E+06	-2
56	6.33E+06	6.33E+06	-4
55	6.71E+06	6.71E+06	4
54	6.66E+06	6.66E+06	-2
53	6.30E+06	6.30E+06	-2
52	6.45E+06	6.45E+06	2
51	6.44E+06	6.44E+06	-2
50	6.54E+06	6.54E+06	4
49	6.30E+06	6.30E+06	0
48	6.36E+06	6.36E+06	2

47	6.25E+06	6.25E+06	0
46	6.39E+06	6.39E+06	0
45	6.33E+06	6.33E+06	2
44	6.65E+06	6.65E+06	4
43	7.05E+06	7.05E+06	-2
42	6.52E+06	6.52E+06	4
41	7.22E+06	7.22E+06	4
40	6.52E+06	6.52E+06	4
39	7.79E+06	7.79E+06	-2
38	6.45E+06	6.45E+06	-4
37	8.33E+06	8.33E+06	-4
36	7.17E+06	7.17E+06	-2
35	1.08E+07	1.08E+07	4
34	6.99E+06	6.99E+06	0
33	1.02E+07	1.02E+07	48
32	8.13E+06	8.13E+06	2
31	6.45E+06	6.45E+06	0
30	7.13E+06	7.13E+06	0
29	5.99E+06	5.99E+06	-2
28	6.69E+06	6.69E+06	0
27	5.74E+06	5.74E+06	-2
26	6.47E+06	6.47E+06	-2
25	5.85E+06	5.85E+06	-2
24	6.49E+06	6.49E+06	0
23	5.84E+06	5.84E+06	2
22	6.73E+06	6.73E+06	-4
21	6.80E+06	6.80E+06	-4
20	6.22E+06	6.22E+06	2
19	6.10E+06	6.10E+06	2
18	6.13E+06	6.13E+06	0
17	6.05E+06	6.05E+06	2
16	6.05E+06	6.05E+06	0
15	6.07E+06	6.07E+06	4
14	6.09E+06	6.09E+06	-4
13	6.12E+06	6.12E+06	2
12	6.14E+06	6.14E+06	4
11	6.16E+06	6.16E+06	-2
10	6.18E+06	6.18E+06	-2
9	6.20E+06	6.20E+06	-4
8	6.22E+06	6.22E+06	0
7	6.24E+06	6.24E+06	4
6	6.26E+06	6.26E+06	2

5	6.28E+06	6.28E+06	2
4	6.30E+06	6.30E+06	2
3	6.32E+06	6.32E+06	4
2	6.34E+06	6.34E+06	1
1	6.36E+06	6.36E+06	5
0	8.69E+06	8.69E+06	0

Appendix 10:
Sample AML Program to Create TIN

```
/* This program was created to specifically turn the soundings
/* data, the shoreline, and the islands for the degree with the
/* southeast corner at latitude 32 and longitude 117.

/* This part loads in the different input files to TINS, then
/* turns them into point coverages to project them.  It then
/* builds them in preparation for creating the large TIN.
createtin 32-117_tin 0
generate 32117e.pbk point
end
tinarc 32-117_tin 32-117_cover point
project cover 32-117_cover 32-117_proj proj.file
build 32-117_proj point

createtin 32-117_shore 0
generate 32117e.pcs line
end
tinarc 32-117_shore 32-117_shcov hull
project cover 32-117_shcov 32-117_shprj proj.file
build 32-117_shprj poly

createtin 32-117_is01 0
generate 32117e01.pis line
end
tinarc 32-117_is01 32-117_is01c hull
project cover 32-117_is01c 32-117_is01p proj.file
build 32-117_is01p poly

createtin 32-117_is02 0
generate 32117e02.pis line
end
tinarc 32-117_is02 32-117_is02c hull
project cover 32-117_is02c 32-117_is02p proj.file
build 32-117_is02p poly

createtin 32-117_is03 0
generate 32117e03.pis line
end
tinarc 32-117_is03 32-117_is03c hull
```

```
project cover 32-117_is03c 32-117_is03p proj.file
build 32-117_is03p poly

createtin 32-117_is04 0
generate 32117e04.pis line
end
tinarc 32-117_is04 32-117_is04c hull
project cover 32-117_is04c 32-117_is04p proj.file
build 32-117_is04p poly

createtin 32-117_is05 0
generate 32117e05.pis line
end
tinarc 32-117_is05 32-117_is05c hull
project cover 32-117_is05c 32-117_is05p proj.file
build 32-117_is05p poly

createtin 32-117_is06 0
generate 32117e06.pis line
end
tinarc 32-117_is06 32-117_is06c hull
project cover 32-117_is06c 32-117_is06p proj.file
build 32-117_is06p poly

createtin 32-117_is07 0
generate 32117e07.pis line
end
tinarc 32-117_is07 32-117_is07c hull
project cover 32-117_is07c 32-117_is07p proj.file
build 32-117_is07p poly

createtin 32-117_is08 0
generate 32117e08.pis line
end
tinarc 32-117_is08 32-117_is08c hull
project cover 32-117_is08c 32-117_is08p proj.file
build 32-117_is08p poly

createtin 32-117_is09 0
generate 32117e09.pis line
end
tinarc 32-117_is09 32-117_is09c hull
```

```
project cover 32-117_is09c 32-117_is09p proj.file
build 32-117_is09p poly

createtin 32-117_is10 0
generate 32117e10.pis line
end
tinarc 32-117_is10 32-117_is10c hull
project cover 32-117_is10c 32-117_is10p proj.file
build 32-117_is10p poly

createtin 32-117_is11 0
generate 32117e11.pis line
end
tinarc 32-117_is11 32-117_is11c hull
project cover 32-117_is11c 32-117_is11p proj.file
build 32-117_is11p poly

createtin 32-117_is12 0
generate 32117e12.pis line
end
tinarc 32-117_is12 32-117_is12c hull
project cover 32-117_is12c 32-117_is12p proj.file
build 32-117_is12p poly

createtin 32-117_is13 0
generate 32117e13.pis line
end
tinarc 32-117_is13 32-117_is13c hull
project cover 32-117_is13c 32-117_is13p proj.file
build 32-117_is13p poly

createtin 32-117_is14 0
generate 32117e14.pis line
end
tinarc 32-117_is14 32-117_is14c hull
project cover 32-117_is14c 32-117_is14p proj.file
build 32-117_is14p poly

createtin 32-117_is15 0
generate 32117e15.pis line
end
tinarc 32-117_is15 32-117_is15c hull
```

```
project cover 32-117_is15c 32-117_is15p proj.file
build 32-117_is15p poly

/* This is the segment that creates the final TIN.
createtin 32-117_finw 0
cover 32-117_proj point
cover 32-117_shprj poly 0 softclip
cover 32-117_is01p poly 0 softerase
cover 32-117_is02p poly 0 softerase
cover 32-117_is03p poly 0 softerase
cover 32-117_is04p poly 0 softerase
cover 32-117_is05p poly 0 softerase
cover 32-117_is06p poly 0 softerase
cover 32-117_is07p poly 0 softerase
cover 32-117_is08p poly 0 softerase
cover 32-117_is09p poly 0 softerase
cover 32-117_is10p poly 0 softerase
cover 32-117_is11p poly 0 softerase
cover 32-117_is12p poly 0 softerase
cover 32-117_is13p poly 0 softerase
cover 32-117_is14p poly 0 softerase
cover 32-117_is15p poly 0 softerase
end

/* This part keeps the directory simple by deleting all of the
/* intermediate coverages.
kill 32-117_tin
kill 32-117_cover
kill 32-117_proj
kill 32-117_shore
kill 32-117_shcov
kill 32-117_shprj
kill 32-117_is01
kill 32-117_is01c
kill 32-117_is01p
kill 32-117_is02
kill 32-117_is02c
kill 32-117_is02p
kill 32-117_is03
kill 32-117_is03c
kill 32-117_is03p
kill 32-117_is04
```

```
kill 32-117_is04c
kill 32-117_is04p
kill 32-117_is05
kill 32-117_is05c
kill 32-117_is05p
kill 32-117_is06
kill 32-117_is06c
kill 32-117_is06p
kill 32-117_is07
kill 32-117_is07c
kill 32-117_is07p
kill 32-117_is08
kill 32-117_is08c
kill 32-117_is08p
kill 32-117_is09
kill 32-117_is09c
kill 32-117_is09p
kill 32-117_is10
kill 32-117_is10c
kill 32-117_is10p
kill 32-117_is11
kill 32-117_is11c
kill 32-117_is11p
kill 32-117_is12
kill 32-117_is12c
kill 32-117_is12p
kill 32-117_is13
kill 32-117_is13c
kill 32-117_is13p
kill 32-117_is14
kill 32-117_is14c
kill 32-117_is14p
kill 32-117_is15
kill 32-117_is15c
kill 32-117_is15p

/* This part gathers the first part of the data by measuring
/* the area above each depth into a table in ARC/INFO.
volume 32-117_finw -100 32-117_volw
volume 32-117_finw -99 32-117_volw
volume 32-117_finw -98 32-117_volw
volume 32-117_finw -97 32-117_volw
```

volume 32-117_finw -96 32-117_volw
volume 32-117_finw -95 32-117_volw
volume 32-117_finw -94 32-117_volw
volume 32-117_finw -93 32-117_volw
volume 32-117_finw -92 32-117_volw
volume 32-117_finw -91 32-117_volw
volume 32-117_finw -90 32-117_volw
volume 32-117_finw -89 32-117_volw
volume 32-117_finw -88 32-117_volw
volume 32-117_finw -87 32-117_volw
volume 32-117_finw -86 32-117_volw
volume 32-117_finw -85 32-117_volw
volume 32-117_finw -84 32-117_volw
volume 32-117_finw -83 32-117_volw
volume 32-117_finw -82 32-117_volw
volume 32-117_finw -81 32-117_volw
volume 32-117_finw -80 32-117_volw
volume 32-117_finw -79 32-117_volw
volume 32-117_finw -78 32-117_volw
volume 32-117_finw -77 32-117_volw
volume 32-117_finw -76 32-117_volw
volume 32-117_finw -75 32-117_volw
volume 32-117_finw -74 32-117_volw
volume 32-117_finw -73 32-117_volw
volume 32-117_finw -72 32-117_volw
volume 32-117_finw -71 32-117_volw
volume 32-117_finw -70 32-117_volw
volume 32-117_finw -69 32-117_volw
volume 32-117_finw -68 32-117_volw
volume 32-117_finw -67 32-117_volw
volume 32-117_finw -66 32-117_volw
volume 32-117_finw -65 32-117_volw
volume 32-117_finw -64 32-117_volw
volume 32-117_finw -63 32-117_volw
volume 32-117_finw -62 32-117_volw
volume 32-117_finw -61 32-117_volw
volume 32-117_finw -60 32-117_volw
volume 32-117_finw -59 32-117_volw
volume 32-117_finw -58 32-117_volw
volume 32-117_finw -57 32-117_volw
volume 32-117_finw -56 32-117_volw
volume 32-117_finw -55 32-117_volw

```
volume 32-117_finw -54 32-117_volw
volume 32-117_finw -53 32-117_volw
volume 32-117_finw -52 32-117_volw
volume 32-117_finw -51 32-117_volw
volume 32-117_finw -50 32-117_volw
volume 32-117_finw -49 32-117_volw
volume 32-117_finw -48 32-117_volw
volume 32-117_finw -47 32-117_volw
volume 32-117_finw -46 32-117_volw
volume 32-117_finw -45 32-117_volw
volume 32-117_finw -44 32-117_volw
volume 32-117_finw -43 32-117_volw
volume 32-117_finw -42 32-117_volw
volume 32-117_finw -41 32-117_volw
volume 32-117_finw -40 32-117_volw
volume 32-117_finw -39 32-117_volw
volume 32-117_finw -38 32-117_volw
volume 32-117_finw -37 32-117_volw
volume 32-117_finw -36 32-117_volw
volume 32-117_finw -35 32-117_volw
volume 32-117_finw -34 32-117_volw
volume 32-117_finw -33 32-117_volw
volume 32-117_finw -32 32-117_volw
volume 32-117_finw -31 32-117_volw
volume 32-117_finw -30 32-117_volw
volume 32-117_finw -29 32-117_volw
volume 32-117_finw -28 32-117_volw
volume 32-117_finw -27 32-117_volw
volume 32-117_finw -26 32-117_volw
volume 32-117_finw -25 32-117_volw
volume 32-117_finw -24 32-117_volw
volume 32-117_finw -23 32-117_volw
volume 32-117_finw -22 32-117_volw
volume 32-117_finw -21 32-117_volw
volume 32-117_finw -20 32-117_volw
volume 32-117_finw -19 32-117_volw
volume 32-117_finw -18 32-117_volw
volume 32-117_finw -17 32-117_volw
volume 32-117_finw -16 32-117_volw
volume 32-117_finw -15 32-117_volw
volume 32-117_finw -14 32-117_volw
volume 32-117_finw -13 32-117_volw
```

```
volume 32-117_finw -12 32-117_volw
volume 32-117_finw -11 32-117_volw
volume 32-117_finw -10 32-117_volw
volume 32-117_finw -9 32-117_volw
volume 32-117_finw -8 32-117_volw
volume 32-117_finw -7 32-117_volw
volume 32-117_finw -6 32-117_volw
volume 32-117_finw -5 32-117_volw
volume 32-117_finw -4 32-117_volw
volume 32-117_finw -3 32-117_volw
volume 32-117_finw -2 32-117_volw
volume 32-117_finw -1 32-117_volw
volume 32-117_finw 0 32-117_volw

/* This section outputs the table into an ASCII file.
tables
select 32-117_volw
unload 32117w.vol tin zmin zmax datum area
q stop
```

Appendix 11:
AML Program

```
/* This program measures the area above each depth from a
/* minimum to a maximum by an interval in a rectangular area
/* from one square degree of the data already created.
/* To save on file space, it creates the TIN and deletes it each
/* time.

/* This starts off ARC/INFO correctly.
&station 9999

/* The following choice decides whether the coordinates will
/* be entered by the menu, one at a time, or by file, many at
/* a time in a specified format.
&s choice := [response 'Please choose either menu (m) or file (f)' ]
&if %choice% = m &then
    &run ca2
&if %choice% = f &then
    &run ca1
&return

/* This calls up the input data menu for the file name.
&menu in2.menu &form

/* This opens the input file for the parameters.
&s fileunit := [open %filin% chek -read]
&if %chek% <> 0 &then &type did not work

/* This reads the number of different degrees that are to be
/* measured, then the number of sections for each degree.
&s NumSect := [read %fileunit% rs]
&type NumSect is %NumSect%
&do a := 1 &to %NumSect% &by 1
   &s NumDeg := [read %fileunit% rs]
&type NumDeg is %NumDeg%
   &s lat := [read %fileunit% rs]
   &s long := [read %fileunit% rs]
   /* This goes to the correct directory.
   &workspace %lat%%long%

  /* This creates the file to contain the hull information.
```

```
/* It also writes the information out.
 &do i := 1 &to %NumDeg% &by 1
    &s fu2 := [open inputf%i% chek -write]
    &s ws1 := [write %fu2% '6']
    &s ct1 := [read %fileunit% rs]
    &s cn1 := [read %fileunit% rs]
    &s ct2 := [read %fileunit% rs]
    &s cn2 := [read %fileunit% rs]
    &s ws2 := [write %fu2% %ct1%,%cn1%,0]
    &s ws3 := [write %fu2% %ct2%,%cn1%,0]
    &s ws4 := [write %fu2% %ct2%,%cn2%,0]
    &s ws5 := [write %fu2% %ct1%,%cn2%,0]
    &s ws6 := [write %fu2% %ct1%,%cn1%,0]
    &s ws7 := [write %fu2% 'end']
    &s ws8 := [write %fu2% 'end']
    &if [close %fu2%] = 0 &then &type closed successfully
 &end

/* This creates, projects and builds the separate TINs for
/* the measurement.
 &do i := 1 &to %NumDeg% &by 1
    createtin cut%i% 0
    generate inputf%i% line
    end
    tinarc cut%i% cov%i% hull
    project cover cov%i% pro%i% proj.file
    build pro%i% poly
 &end

 createtin %lat%-%long%_tin 0
 generate %lat%%long%e.pbk point
 end
 tinarc %lat%-%long%_tin %lat%-%long%_cover point
 project cover %lat%-%long%_cover %lat%-%long%_proj proj.file
 build %lat%-%long%_proj point

 createtin %lat%-%long%_shore 0
 generate %lat%%long%e.pcs line
 end
 tinarc %lat%-%long%_shore %lat%-%long%_shcov hull
 project cover %lat%-%long%_shcov %lat%-%long%_shprj proj.file
 build %lat%-%long%_shprj poly
```

```
/* This does each of the islands, if they exist, separately.
&do i := 1 &to 290 &by 1
    &if %i% < 10 &then
       &setvar term := %lat%%long%e0%i%.pis
    &if %i% > 9 &then
    &if %i% < 100 &then
       &setvar term := %lat%%long%e%i%.pis
     &if %i% > 99 &then
        &setvar term := %lat%%long%%i%.pis
     &if %i% < 10 &then
              &setvar fac := e0%i%
     &if %i% > 9 &then
              &if %i% < 100 &then
          &setvar fac := e%i%
    &if %i% > 99 &then
       &setvar fac := %i%
    &if [exists %term%] &then
     &do
       createtin %lat%-%long%_is%fac% 0
       generate %lat%%long%%fac%.pis line
       end
       tinarc %lat%-%long%_is%fac% %lat%-%long%_is%fac%c hull
       project cover %lat%-%long%_is%fac%c %lat%-%long%_is%fac%p proj.file
       build %lat%-%long%_is%fac%p poly
   &end
&end

/* This creates the combined TIN, for the measurement to
/* be done from.
createtin area 0
cover %lat%-%long%_proj point
&type process %lat%-%long%_proj
cover %lat%-%long%_shprj poly 0 softclip
&type process %lat%-%long%_shprj
&do i := 1 &to 290 &by 1
   &if %i% < 10 &then
              &setvar fac := e0%i%
   &if %i% > 9 &then
              &if %i% < 100 &then
       &setvar fac := e%i%
   &if %i% > 99 &then
```

```
      &setvar fac := %i%
    &setvar term := %lat%-%long%_is%fac%p
    &setvar t2 := %lat%%long%%fac%.pis
    &if [exists %t2%] &then
      cover %term% poly 0 softerase
&type process %term%
&end
&type done with loop
&do i := 1 &to %NumDeg% &by 1
   cover pro%i% poly 0 softclip
&end
&type pro
end
&type done with TIN

/* This removes the intermediate coverages.
&do i := 1 &to 290 &by 1
    &if %i% < 10 &then
                &setvar fac = e0%i%
    &if %i% > 9 &then
                &if %i% < 100 &then
          &setvar fac = e%i%
    &if %i% > 99 &then
       &setvar fac = %i%
    &setvar term := %lat%-%long%_is%fac%
    &setvar t2 := %lat%%long%%fac%.pis
   &if [exists %t2%] &then
       &do
          kill %term%
          kill %term%c
          kill %term%p
      &end
&end
kill %lat%-%long%_tin
kill %lat%-%long%_cover
kill %lat%-%long%_proj
kill %lat%-%long%_shore
kill %lat%-%long%_shcov
kill %lat%-%long%_shprj
&do i := 1 &to %NumDeg% &by 1
    &s ds1 := [delete ent%i%]
    &s ds1 := [delete inputf%i%]
```

```
    kill cut%i%
    kill cov%i%
    kill pro%i%
&end

/* This measures the areas into a table.
&s mindep := [read %fileunit% rs]
&s maxdep := [read %fileunit% rs]
&s int := [read %fileunit% rs]
&s outfile := [read %fileunit% rs]
&do d := %mindep% &to %maxdep% &by %int%
   volume area %d% vol%outfile%
&end
&type end of volumes

/* This outputs the table to an ASCII file.
&type output file is %outfile%
&s filout = [open %outfile% check -write]
tables
select vol%outfile%
unload %outfile% tin zmin zmax datum area
q stop

/* This returns the setup to normal.
kill area
&workspace ..

&end
&if [close %fileunit%] = 0 &then &type closed successfully
&return

/* This calls up the input data menu for the section input.
&menu input.menu &form

/* This goes to the correct directory.
&workspace %lat%%long%
&s fileunit := [open inputf chek -write]
&if %chek% <> 0 &then &type did not work

/* This creates the file to contain the hull information.
/* It also writes the information out.
&s ws1 := [write %fileunit% '6']
```

```
&s ws2 := [write %fileunit% %ct1%,%cn1%,0]
&s ws3 := [write %fileunit% %ct2%,%cn1%,0]
&s ws4 := [write %fileunit% %ct2%,%cn2%,0]
&s ws5 := [write %fileunit% %ct1%,%cn2%,0]
&s ws6 := [write %fileunit% %ct1%,%cn1%,0]
&s ws7 := [write %fileunit% 'end']
&s ws8 := [write %fileunit% 'end']
&if [close %fileunit%] = 0 &then &type closed successfully

/* This creates, projects and builds the separate TINs for
/* the measurement.
createtin cut 0
generate inputf line
end
tinarc cut cov hull
project cover cov pro proj.file
build pro poly

createtin %lat%-%long%_tin 0
generate %lat%%long%e.pbk point
end
tinarc %lat%-%long%_tin %lat%-%long%_cover point
project cover %lat%-%long%_cover %lat%-%long%_proj proj.file
build %lat%-%long%_proj point

createtin %lat%-%long%_shore 0
generate %lat%%long%e.pcs line
end
tinarc %lat%-%long%_shore %lat%-%long%_shcov hull
project cover %lat%-%long%_shcov %lat%-%long%_shprj proj.file
build %lat%-%long%_shprj poly

/* This does each of the islands, if they exist, separately.
&do i := 1 &to 290 &by 1
    &if %i% < 10 &then
                &setvar term := %lat%%long%e0%i%.pis
    &if %i% > 9 &then
                &if %i% < 100 &then
          &setvar term := %lat%%long%e%i%.pis
    &if %i% > 99 &then
       &setvar term := %lat%%long%%i%.pis
    &if %i% < 10 &then
```

```
                &setvar fac := e0%i%
    &if %i% > 9 &then
                &if %i% < 100 &then
          &setvar fac := e%i%
    &if %i% > 99 &then
       &setvar fac := %i%
    &if [exists %term%] &then
      &do
          createtin %lat%-%long%_is%fac% 0
          generate %lat%%long%%fac%.pis line
          end
          tinarc %lat%-%long%_is%fac% %lat%-%long%_is%fac%c hull
          project cover %lat%-%long%_is%fac%c %lat%-%long%_is%fac%p proj.file
          build %lat%-%long%_is%fac%p poly
      &end
&end

/* This creates the combined TIN, for the measurement to
/* be done from.
createtin area 0
cover %lat%-%long%_proj point
&type process %lat%-%long%_proj
cover %lat%-%long%_shprj poly 0 softclip
&type process %lat%-%long%_shprj
&do i := 1 &to 290 &by 1
    &if %i% < 10 &then
                &setvar fac := e0%i%
    &if %i% > 9 &then
                &if %i% < 100 &then
          &setvar fac := e%i%
    &if %i% > 99 &then
       &setvar fac := %i%
    &setvar term := %lat%-%long%_is%fac%p
    &setvar t2 := %lat%%long%%fac%.pis
    &if [exists %t2%] &then
      cover %term% poly 0 softerase
&type process %term%
&end
&type done with loop
cover pro poly 0 softclip
&type pro
end
```

```
&type done with TIN

/* This removes the intermediate coverages.
kill pro
&do i := 1 &to 290 &by 1
    &if %i% < 10 &then
                &setvar fac = e0%i%
    &if %i% > 9 &then
                &if %i% < 100 &then
          &setvar fac = e%i%
    &if %i% > 99 &then
       &setvar fac = %i%
    &setvar term := %lat%-%long%_is%fac%
    &setvar t2 := %lat%%long%%fac%.pis
    &if [exists %t2%] &then
       &do
          kill %term%
          kill %term%c
          kill %term%p
       &end
&end
kill %lat%-%long%_tin
kill %lat%-%long%_cover
kill %lat%-%long%_proj
kill %lat%-%long%_shore
kill %lat%-%long%_shcov
kill %lat%-%long%_shprj
&s ds1 := [delete inputf]
&s ds1 := [delete ent]
kill cut
kill cov

/* This measures the areas into a table.
&do d := %mnd% &to %mxd% &by %int%
   volume area %d% vol%of%
&end

/* This outputs the table to an ASCII file.
&s fileout = [open ../%of% check -write]
tables
select vol%of%
unload %fileout% tin zmin zmax datum area
```

```
q stop

/* This returns the setup to normal.
kill area
&workspace ..
&return
```